TOTAL MAXIMUM DAILY LOAD (TMDL)

for

E. Coli

in the

Lower Cumberland (Cheatham Lake) Watershed

(HUC 05130202)

Cheatham, Davidson, Robertson, Sumner, and Williamson Counties, Tennessee

FINAL

Prepared by:

Tennessee Department of Environment and Conservation
Division of Water Pollution Control
6th Floor L & C Tower
401 Church Street
Nashville, TN 37243-1534

Submitted April 1, 2008
Approved by EPA Region 4 – April 15, 2008

DEPARTMENT OF ENVIRONMENT & CONSERVATION

TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF FIGURES (cont'd)

LIST OF FIGURES (cont'd)

LIST OF FIGURES (cont'd)

LIST OF TABLES

LIST OF TABLES (cont'd)

LIST OF TABLES (cont'd)

LIST OF TABLES (cont'd)

LIST OF ABBREVIATIONS

ADB	Assessment Database
AFO	Animal Feeding Operation
BMP	Best Management Practices
BST	Bacteria Source Tracking
CAFO	Concentrated Animal Feeding Operation
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second
CFU	Colony Forming Units
DEM	Digital Elevation Model
DWPC	Division of Water Pollution Control
E. coli	Escherichia coli
EPA	Environmental Protection Agency
GIS	Geographic Information System
HSPF	Hydrological Simulation Program - Fortran
HUC	Hydrologic Unit Code
LA	Load Allocation
LDC	Load Duration Curve
LSPC	Loading Simulation Program in C^{++}
MGD	Million Gallons per Day
MOS	Margin of Safety
MRLC	Multi-Resolution Land Characteristic
MS4	Municipal Separate Storm Sewer System
MST	Microbial Source Tracking
NHD	National Hydrography Dataset
NMP	Nutrient Management Plan
NPS	Nonpoint Source
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
PCR	Polymerase Chain Reaction
PDFE	Percent of Days Flow Exceeded
PFGE	Pulsed Field Gel Electrophoresis
Rf3	Reach File v.3
RM	River Mile
SSO	Sanitary Sewer Overflow
STP	Sewage Treatment Plant
SWMP	Storm Water Management Program
TDA	Tennessee Department of Agriculture
TDEC	Tennessee Department of Environment & Conservation
TDOT	Tennessee Department of Transportation
TMDL	Total Maximum Daily Load
TWRA	Tennessee Wildlife Resources Agency
USGS	United States Geological Survey
UCF	Unit Conversion Factor
WCS	Watershed Characterization System
WLA	Waste Load Allocation
WWTF	Wastewater Treatment Facility

SUMMARY SHEET

Total Maximum Daily Load for E. coli in Lower Cumberland Watershed (HUC 05130202)

Impaired Waterbody Information

State: Tennessee
Counties: Davidson, Sumner, and Williamson
Watershed: Lower Cumberland (HUC 05130202)
Constituents of Concern: E. coli

Impaired Waterbodies Addressed in This Document (from the Final 2006 303(d) List):

Waterbody ID	Waterbody	Miles Impaired
TN05130202007 – 0100	SIMS BRANCH	1.5
TN05130202007 – 0300	FINLEY BRANCH	1.2
TN05130202007 – 1400	SEVENMILE CREEK	2.4
TN05130202007 – 1410	SHASTA BRANCH	1.0
TN05130202007 – 1450	SEVENMILE CREEK	2.0
TN05130202007 – 1500	PAVILLION BRANCH	1.3
TN05130202007 – 3000	MILL CREEK	5.9
TN05130202007 – 5000	MILL CREEK	8.1
TN05130202010 – 0200	DRAKES BRANCH	2.7
TN05130202010 – 0300	DRY FORK	9.9
TN05130202010 – 0400	EARTHMAN FORK	11.0
TN05130202010 – 0600	CUMMINGS BRANCH	2.6
TN05130202010 – 0700	LITTLE CREEK	1.1
TN05130202010 – 0800	EWING CREEK	17.6
TN05130202010 – 1000	WHITES CREEK	2.9
TN05130202023 – 0100	EAST FORK BROWN'S CREEK	2.2
TN05130202023 – 0300	WEST FORK BROWN'S CREEK	3.6
TN05130202023 – 1000	BROWN'S CREEK	0.2
TN05130202023 – 2000	BROWN'S CREEK	4.1
TN05130202027 – 1000	DRY CREEK	0.5
TN05130202202 – 1000	PAGES BRANCH	0.6
TN05130202202 – 2000	PAGES BRANCH	4.5
TN05130202209 – 1000	COOPER CREEK	3.9

Waterbody ID	Waterbody	Miles Impaired
TN05130202212 – 0100	NEELEYS BRANCH	1.7
TN05130202212 – 1000	GIBSON CREEK	3.7
TN05130202220 – 0100	LUMSLEY FORK	4.7
TN05130202220 – 0200	WALKERS CREEK	7.8
TN05130202220 – 0300	SLATERS CREEK	11.3
TN05130202220 – 1000	MANSKERS CREEK	7.9
TN05130202220 – 2000	MANSKERS CREEK	7.6
TN05130202314 – 0100	UNNAMED TRIB TO RICHLAND CREEK	1.1
TN05130202314 – 0200	MURPHY ROAD BRANCH	1.5
TN05130202314 – 0300	BOSLEY SPRINGS BRANCH	1.5
TN05130202314 – 0400	SUGARTREE CREEK	4.3
TN05130202314 – 0700	VAUGHNS GAP BRANCH	0.6
TN05130202314 – 0750	VAUGHNS GAP BRANCH	1.9
TN05130202314 – 0800	JOCELYN HOLLOW BRANCH	2.0
TN05130202314 – 1000	RICHLAND CREEK	1.9
TN05130202314 – 2000	RICHLAND CREEK	6.7
TN05130202314 – 3000	RICHLAND CREEK	4.0

Designated Uses:

The designated use classifications for waterbodies in the Lower Cumberland Watershed include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation. Portions of Mill Creek (mouth to Mile 11.5), and all of Whites Creek and Ewing Creek are also designated for industrial water supply.

Water Quality Targets:

Derived from *State of Tennessee Water Quality Standards, Chapter 1200-4-3, General Water Quality Criteria, January, 2004* for recreation use classification (most stringent):

> The concentration of the E. coli group shall not exceed 126 colony forming units per 100 mL, as a geometric mean based on a minimum of 5 samples collected from a given sampling site over a period of not more than 30 consecutive days with individual samples being collected at intervals of not less than 12 hours. For the purposes of determining the geometric mean, individual samples having an E. coli concentration of less than 1 per 100 mL shall be considered as having a concentration of 1 per 100 mL.
>
> Additionally, the concentration of the E. coli group in any individual sample taken from a lake, reservoir, State Scenic River, or Tier II or III stream (1200-

4-3-.06) shall not exceed 487 colony forming units per 100 mL. The concentration of the E. coli group in any individual sample taken from any other waterbody shall not exceed 941 colony forming units per 100 mL.

Note: At the time of this TMDL analysis, high quality waters were designated as Tier II and Tier III streams. The proposed revised water quality standards redefine high quality waters as Exceptional Tennessee Waters. For further information on Tennessee's current general water quality standards, see:

http://www.state.tn.us/sos/rules/1200/1200-04/1200-04-03.pdf.

For further information on the proposed revised general water quality standards and Tennessee's Antidegradation Statement, including the definition of Exceptional Tennessee Waters, see:

http://www.state.tn.us/environment/wpc/publications/1200_04_03_2nd_draft.pdf.

TMDL Scope:

Waterbodies identified on the Final 2006 303(d) list as impaired due to E. coli. TMDLs were developed for impaired waterbodies on a HUC-12 subwatershed or waterbody drainage area basis.

Analysis/Methodology:

The TMDLs for impaired waterbodies in the Lower Cumberland watershed were developed using a load duration curve methodology to assure compliance with the E. coli 126 CFU/100 mL geometric mean and the 487 CFU/100 mL maximum water quality criteria for lakes, reservoirs, State Scenic Rivers, or Tier II or Tier III waterbodies and 941 CFU/100 mL maximum water quality criterion for all other waterbodies. A duration curve is a cumulative frequency graph that represents the percentage of time during which the value of a given parameter is equaled or exceeded. Load duration curves are developed from flow duration curves and can illustrate existing water quality conditions (as represented by loads calculated from monitoring data), how these conditions compare to desired targets, and the region of the waterbody flow zone represented by these existing loads. Load duration curves were also used to determine percent load reduction goals to meet the target maximum loading for E. coli. When sufficient data were available, load reductions were also determined based on geometric mean criterion.

Critical Conditions:

Water quality data collected over a period of up to 10 years for load duration curve analysis were used to assess the water quality standards representing a range of hydrologic and meteorological conditions.

For each impaired waterbody, critical conditions were determined by evaluating the percent load reduction goals, for each hydrologic flow zone, to meet the target (TMDL) loading for E. coli. The percent load reduction goal of the greatest magnitude corresponds with the critical flow zone.

Seasonal Variation:

The 10-year period used for LSPC model simulation and for load duration curve analysis included all seasons and a full range of flow and meteorological conditions.

Margin of Safety (MOS):

Explicit MOS = 10% of the E. coli water quality criteria for each impaired subwatershed or drainage area.

Summary of TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Lower Cumberland Watershed (HUC 05130202)

HUC-12 Subwatershed (05130202__) or Drainage Area (DA)	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	MOS	WLAs			LAs
					WWTFs [a]	Leaking Collection Systems	MS4s	
			[CFU/day]	[CFU/day]	[CFU/day]	[CFU/day]	[CFU/day/acre]	[CFU/day/acre]
0101	Cooper Creek	TN05130202209 – 1000	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	$8.862 \times 10^{6} * Q$	$8.862 \times 10^{6} * Q$
	Dry Creek	TN05130202027 – 1000	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	$3.826 \times 10^{6} * Q$	$3.826 \times 10^{6} * Q$
	Gibson Creek	TN05130202212 – 1000	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	$7.727 \times 10^{6} * Q$	$7.727 \times 10^{6} * Q$
	Neeleys Branch	TN05130202212 – 0100	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	$1.526 \times 10^{7} * Q$	$1.526 \times 10^{7} * Q$
0102	Lumsley Fork	TN05130202220 – 0100	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	$1.008 \times 10^{7} * Q$	$1.008 \times 10^{7} * Q$
	Manskers Creek	TN05130202220 – 1000	$1.20 \times 10^{10} * Q$	$1.20 \times 10^{9} * Q$	NA	0	$3.697 \times 10^{5} * Q$	$3.697 \times 10^{5} * Q$
	Manskers Creek	TN05130202220 – 2000	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	$1.200 \times 10^{6} * Q$	$1.200 \times 10^{6} * Q$
	Slaters Creek	TN05130202220 – 0300	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	$4.374 \times 10^{6} * Q$	$4.374 \times 10^{6} * Q$
	Walkers Creek	TN05130202220 – 0200	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	$2.979 \times 10^{6} * Q$	$2.979 \times 10^{6} * Q$
0103	Browns Creek	TN05130202023 – 1000	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	$2.070 \times 10^{6} * Q$	$2.070 \times 10^{6} * Q$
	Browns Creek	TN05130202023 – 2000	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	$2.150 \times 10^{6} * Q$	$2.150 \times 10^{6} * Q$
	East Fork Browns Creek	TN05130202023 – 0100	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	$1.810 \times 10^{7} * Q$	$1.810 \times 10^{7} * Q$
	West Fork Browns Creek	TN05130202023 – 0300	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	$9.526 \times 10^{6} * Q$	$9.526 \times 10^{6} * Q$
	Pages Branch	TN05130202202 – 1000	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	$1.072 \times 10^{7} * Q$	$1.072 \times 10^{7} * Q$
	Pages Branch	TN05130202202 – 2000	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	$1.707 \times 10^{7} * Q$	$1.707 \times 10^{7} * Q$
0105	Cummings Branch	TN05130202010 – 0600	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	$1.433 \times 10^{7} * Q$	$1.433 \times 10^{7} * Q$
	Drakes Branch	TN05130202010 – 0200	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	$1.663 \times 10^{7} * Q$	$1.663 \times 10^{7} * Q$
	Dry Fork	TN05130202010 – 0300	$2.30 \times 10^{10} * Q$	$2.30 \times 10^{9} * Q$	NA	0	$7.594 \times 10^{6} * Q$	$7.594 \times 10^{6} * Q$

Summary (cont'd) of TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Lower Cumberland Watershed (HUC 05130202)

HUC-12 Subwatershed (05130202__) or Drainage Area (DA)	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	MOS	WLAs			LAs
					WWTFs [a]	Leaking Collection Systems	MS4s	
			[CFU/day]	[CFU/day]	[CFU/day]	[CFU/day]	[CFU/day/acre]	[CFU/day/acre]
0105	Earthman Fork	TN05130202010 – 0400	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	5.158×10^{6} * Q	5.158×10^{6} * Q
	Ewing Creek	TN05130202010 – 0800	1.20×10^{10} * Q	1.20×10^{9} * Q	NA	0	1.273×10^{6} * Q	1.273×10^{6} * Q
	Little Creek	TN05130202010 – 0700	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	6.263×10^{6} * Q	6.263×10^{6} * Q
	Whites Creek	TN05130202010 – 1000	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	5.251×10^{5} * Q	5.251×10^{5} * Q
0106	Bosley Springs Branch	TN05130202314 – 0300	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	1.434×10^{7} * Q	1.434×10^{7} * Q
	Jocelyn Hollow Branch	TN05130202314 – 0800	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	1.249×10^{7} * Q	1.249×10^{7} * Q
	Murphy Road Branch	TN05130202314 – 0200	1.20×10^{10} * Q	1.20×10^{9} * Q	NA	0	2.166×10^{7} * Q	2.166×10^{7} * Q
	Richland Creek	TN05130202314 – 1000	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	1.214×10^{6} * Q	1.214×10^{6} * Q
	Richland Creek	TN05130202314 – 2000	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	7.055×10^{5} * Q	7.055×10^{5} * Q
	Richland Creek	TN05130202314 – 3000	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	1.605×10^{6} * Q	1.605×10^{6} * Q
	Sugartree Creek	TN05130202314 – 0400	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	6.917×10^{6} * Q	6.917×10^{6} * Q
	Unnamed Tributary to Richland Creek	TN05130202314 – 0100	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	1.457×10^{8} * Q	1.457×10^{8} * Q
	Vaughns Gap Branch	TN05130202314 – 0700	1.20×10^{10} * Q	1.20×10^{9} * Q	NA	0	5.950×10^{6} * Q	5.950×10^{6} * Q
	Vaughns Gap Branch	TN05130202314 – 0750	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	1.140×10^{7} * Q	1.140×10^{7} * Q
0201	Mill Creek	TN05130202007 – 5000	1.20×10^{10} * Q	1.20×10^{9} * Q	NA	0	4.876×10^{5} * Q	4.876×10^{5} * Q
0202	Finley Branch	TN05130202007 – 0300	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	5.951×10^{7} * Q	5.951×10^{7} * Q
	Mill Creek	TN05130202007 – 3000	1.20×10^{10} * Q	1.20×10^{9} * Q	NA	0	2.467×10^{5} * Q	2.467×10^{5} * Q
	Pavillion Branch	TN05130202007 – 1500	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	3.685×10^{7} * Q	3.685×10^{7} * Q

Summary (cont'd) of TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Lower Cumberland Watershed (HUC 05130202)

HUC-12 Subwatershed (05130202__) or Drainage Area (DA)	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	MOS	WLAs			LAs
					WWTFs [a]	Leaking Collection Systems	MS4s	
			[CFU/day]	[CFU/day]	[CFU/day]	[CFU/day]	[CFU/day/acre]	[CFU/day/acre]
0202	Sevenmile Creek	TN05130202007 – 1400	1.20×10^{10} * Q	1.20×10^{9} * Q	NA	0	9.941×10^{5} * Q	9.941×10^{5} * Q
	Sevenmile Creek	TN05130202007 – 1450	1.20×10^{10} * Q	1.20×10^{9} * Q	NA	0	2.289×10^{6} * Q	2.289×10^{6} * Q
	Shasta Branch	TN05130202007 – 1410	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	4.901×10^{7} * Q	4.901×10^{7} * Q
	Sims Branch	TN05130202007 – 0100	1.20×10^{10} * Q	1.20×10^{9} * Q	NA	0	4.005×10^{6} * Q	4.005×10^{6} * Q

Notes: NA = Not Applicable.
a. WLAs for WWTFs are expressed as E. coli loads (CFU/day). All current and future WWTFs must meet water quality standards at the point of discharge as specified in their NPDES permit; at no time shall concentration be greater than the appropriate E. coli standard (487 CFU/100 mL or 941 CFU/100 mL).

E. COLI TOTAL MAXIMUM DAILY LOAD (TMDL)
LOWER CUMBERLAND WATERSHED (HUC 05130202)

1.0 INTRODUCTION

Section 303(d) of the Clean Water Act requires each state to list those waters within its boundaries for which technology based effluent limitations are not stringent enough to protect any water quality standard applicable to such waters. Listed waters are prioritized with respect to designated use classifications and the severity of pollution. In accordance with this prioritization, states are required to develop Total Maximum Daily Loads (TMDLs) for those waterbodies that are not attaining water quality standards. State water quality standards consist of designated uses for individual waterbodies, appropriate numeric and narrative water quality criteria protective of the designated uses, and an antidegradation statement. The TMDL process establishes the maximum allowable loadings of pollutants for a waterbody that will allow the waterbody to maintain water quality standards. The TMDL may then be used to develop controls for reducing pollution from both point and nonpoint sources in order to restore and maintain the quality of water resources (USEPA, 1991).

2.0 SCOPE OF DOCUMENT

This document presents details of TMDL development for waterbodies in the Lower Cumberland (Cheatham Lake) Watershed, identified on the Final 2006 303(d) list as not supporting designated uses due to E. coli. TMDL analyses were performed primarily on a 12-digit hydrologic unit area (HUC-12) basis. In some cases, where appropriate, TMDLs were developed for an impaired waterbody drainage area only.

3.0 WATERSHED DESCRIPTION

The Lower Cumberland Watershed (HUC 05130202) is located in Middle Tennessee (Figure 1), primarily in Davidson County. The Lower Cumberland Watershed lies within one Level III ecoregion (Interior Plateau) and contains four Level IV ecoregions as shown in Figure 2 (USEPA, 1997):

- The **Western Pennyroyal Karst (71e)** is a flatter area of irregular plains, with fewer perennial streams, compared to the open hills of the Western Highland Rim (71f). Small sinkholes and depressions are common. The productive soils of this notable agricultural area are formed mostly from a thin loess mantle over residuum of Mississippian-age limestones. Most of the region is cultivated or in pasture; tobacco and livestock are the principal agricultural products, with some corn, soybeans, and small grains. The natural vegetation consisted of oak-hickory forest with mosaics of bluestem prairie. The barrens of Kentucky that extended south into Stewart, Montgomery, and Robertson counties, were once some of the largest natural grasslands in Tennessee.

- The **Western Highland Rim (71f)** is characterized by dissected, rolling terrain of open hills, with elevations of 400 to 1000 feet. The geologic base of Mississippian-age limestone, chert, and shale is covered by soils that tend to be cherty, acidic and low to moderate in fertility. Streams are characterized by coarse chert gravel and sand substrates with areas of bedrock, moderate gradients, and relatively clear water. The oak-hickory natural vegetation was mostly deforested in the mid to late 1800's, in conjunction with the iron ore related mining and smelting of the mineral limonite, but now the region is again heavily forested. Some agriculture occurs on the flatter areas between streams and in the stream and river valleys: mostly hay, pasture, and cattle, with some cultivation of corn and tobacco.

- The **Outer Nashville Basin (71h)** is a more heterogeneous region than the Inner Nashville Basin, with more rolling and hilly topography and slightly higher elevations. The region encompasses most all of the outer areas of the generally non-cherty Ordovician limestone bedrock. The higher hills and knobs are capped by the more cherty Mississippian-age formations, and some Devonian-age Chattanooga shale, remnants of the Highland Rim. The region's limestone rocks and soils are high in phosphorus, and commercial phosphate is mined. Deciduous forests with pasture and cropland are the dominant land covers. Streams are low to moderate gradient, with productive nutrient-rich waters, resulting in algae, rooted vegetation, and occasionally high densities of fish. The Nashville Basin as a whole has a distinctive fish fauna, notable for fish that avoid the region, as well as those that are present.
- The **Inner Nashville Basin (71i)** is less hilly and lower than the Outer Nashville Basin. Outcrops of the Ordovician-age limestone are common, and the generally shallow soils are redder and lower in phosphorus than those of the Outer Basin. Streams are lower gradient than surrounding regions, often flowing over large expanses of limestone bedrock. The most characteristic hardwoods within the Inner Basin are a maple-oak-hickory-ash association. The limestone cedar glades of Tennessee, a unique mixed grassland/forest/cedar glades vegetation type with many endemic species, are located primarily on the limestone of the Inner Nashville Basin. The more xeric, open characteristics and shallow soils of the cedar glades also result in a distinct distribution of amphibian and reptile species.

The Lower Cumberland Watershed, located in Cheatham, Davidson, Robertson, Sumner, and Williamson Counties, Tennessee, has a drainage area of approximately 647 square miles (mi^2). Watershed land use distribution is based on the Multi-Resolution Land Characteristic (MRLC) databases derived from Landsat Thematic Mapper digital images from the period 1990-1993. Although changes in the land use of the Lower Cumberland Watershed have occurred since 1993 as a result of development, this is the most current land use data available. Land use for the Lower Cumberland Watershed is summarized in Table 1 and shown in Figure 3. Predominant land use in the Lower Cumberland Watershed is forest (60.2%) followed by pasture (11.6%). Urban areas represent approximately 16.6% of the total drainage area of the watershed. Details of land use distribution of impaired subwatersheds in the Lower Cumberland Watershed are presented in Appendix A.

Figure 1. Location of the Lower Cumberland Watershed.

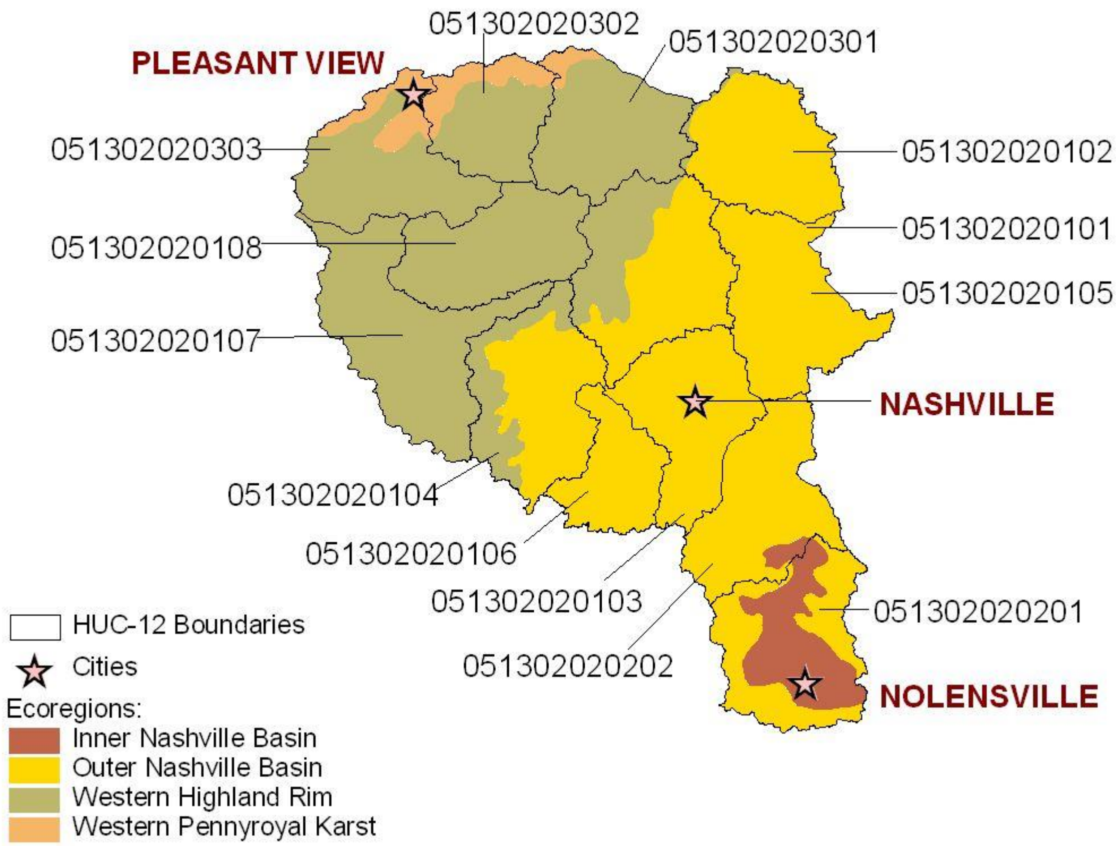

Figure 2. Level IV Ecoregions in the Lower Cumberland (Cheatham Lake) Watershed. Locations of Nashville, Nolensville, and Pleasantview are shown for reference.

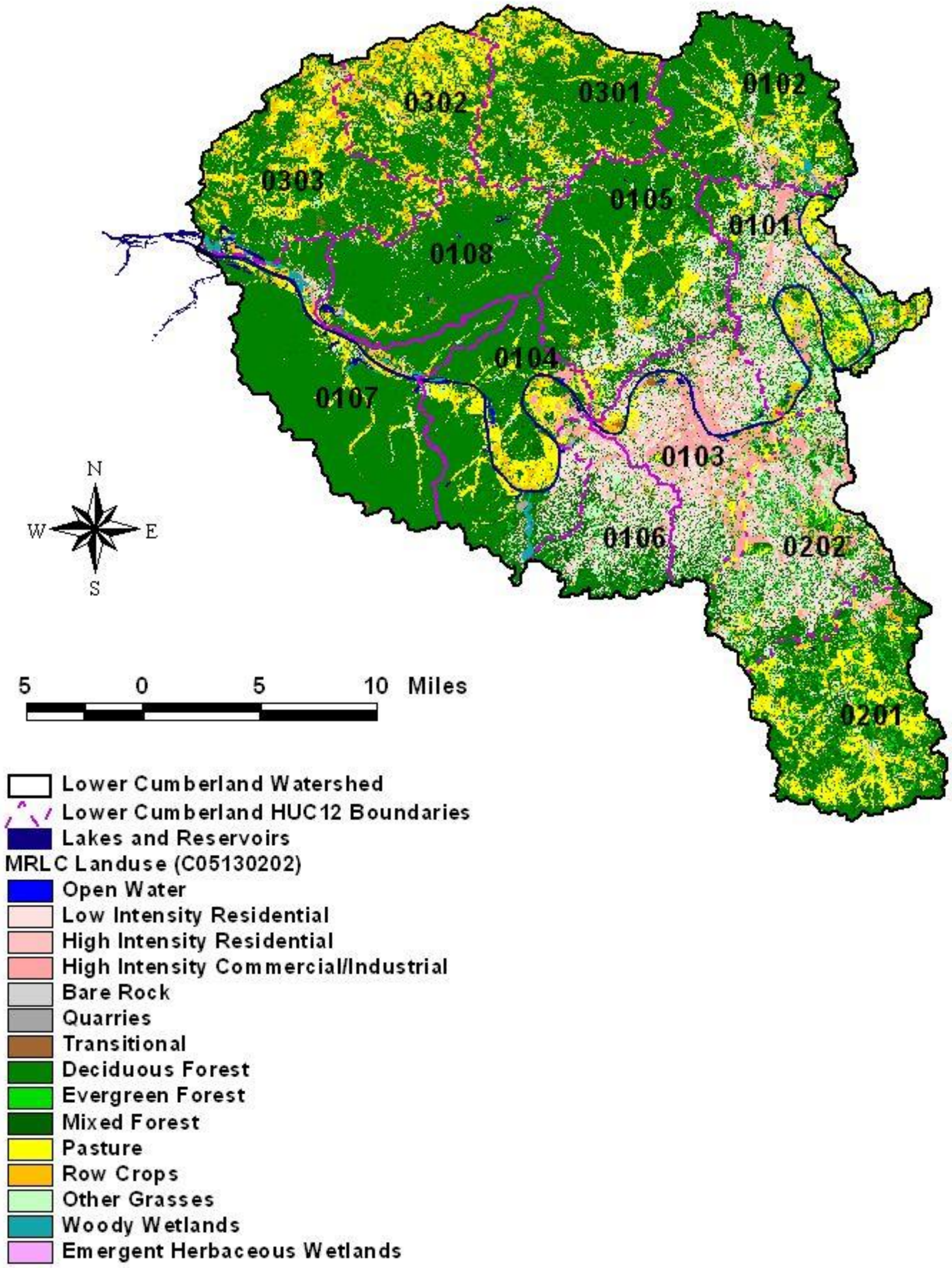

Figure 3. Land Use Characteristics of the Lower Cumberland Watershed.

Table 1. MRLC Land Use Distribution – Lower Cumberland Watershed

Land Use	Area	
	[acres]	[%]
Bare Rock/Sand Clay	1	0.0
Deciduous Forest	179,103	43.2
Emergent Herbaceous Wetlands	150	0.0
Evergreen Forest	17,371	4.2
High Intensity Commercial/Industrial/ Transportation	17,879	4.3
High Intensity Residential	10,193	2.5
Low Intensity Residential	40,848	9.9
Mixed Forest	52,982	12.8
Open Water	5,433	1.3
Other Grasses (Urban/recreational)	14,559	3.5
Pasture/Hay	47,898	11.6
Quarries/Strip Mines/ Gravel Pits	334	0.1
Row Crops	24,293	5.9
Transitional	801	0.2
Woody Wetlands	2,379	0.6
Total	**414,225**	**100.0**

4.0 PROBLEM DEFINITION

The State of Tennessee's final 2006 303(d) list (TDEC, 2006), http://state.tn.us/environment/wpc/publications/303d2006.pdf, was approved by the U.S. Environmental Protection Agency (EPA), Region IV in October of 2006. This list identified portions of thirty-two (32) waterbodies in the Lower Cumberland Watershed as not fully supporting designated use classifications due, in part, to E. coli (see Table 2 & Figure 4). The designated use classifications for these waterbodies include fish and aquatic life, irrigation, livestock watering & wildlife, and recreation. Portions of Mill Creek (mouth to Mile 11.5) and all of Whites Creek and Ewing Creek are also designated for industrial water supply.

5.0 WATER QUALITY CRITERIA & TMDL TARGET

As previously stated, the designated use classifications for the Lower Cumberland waterbodies include fish & aquatic life, recreation, irrigation, and livestock watering & wildlife. Of the use classifications with numeric criteria for E. coli, the recreation use classification is the most stringent and will be used to establish target levels for TMDL development. The coliform water quality criteria, for protection of the recreation use classification, is established by *State of Tennessee Water Quality Standards, Chapter 1200-4-3, General Water Quality Criteria, January 2004* (TDEC, 2004a).

All of Mill Creek, Sevenmile Creek, and Sims Branch have been classified as high quality waters due to the presence of the Federal endangered Nashville Crayfish. Portions of Jocelyn Hollow Branch and Richland Creek have been classified as high quality waters due to their presence in the Belle Meade Mansion State Historic Area. Portions of Manskers Creek (Moss-Wright Park and Bowen-Campbell House), Ewing Creek (Cedar Hill Park), Richland Creek (Centennial Park), Murphy Road Branch (Richland-West End Historic District), and Vaughns Gap Branch (Percy Warner Park) also have been classified as high quality waters. As of February 8, 2008, none of the other impaired waterbodies in the Lower Cumberland Watershed have been designated as high quality waters.

For further information concerning Tennessee's general water quality criteria and Tennessee's Antidegradation Statement, including the definition of high quality waters, see:

http://www.state.tn.us/sos/rules/1200/1200-04/1200-04-03.pdf .

The geometric mean standard for the E. coli group of 126 colony forming units per 100 ml (CFU/100 ml) and the sample maximum of 487 CFU/100 ml have been selected as the appropriate numerical targets for TMDL development for impaired waterbodies classified as lakes, reservoirs, State Scenic Rivers, or Tier II or Tier III streams. The geometric mean standard for the E. coli group of 126 colony forming units per 100 ml (CFU/100 ml) and the sample maximum of 941 CFU/100 ml have been selected as the appropriate numerical targets for TMDL development for the other impaired waterbodies.

Table 2 Final 2006 303(d) List for E. coli Impaired Waterbodies – Lower Cumberland Watershed

Waterbody ID	Impacted Waterbody	Miles/Acres Impaired	Cause (Pollutant)	Pollutant Source
TN05130202007 – 0100	SIMS BRANCH	1.5	Nutrients Low dissolved oxygen Other Habitat Alteration Escherichia coli	Discharges from MS4 area Industrial Permitted Stormwater Hydromodification
TN05130202007 – 0300	FINLEY BRANCH	4.0	Chlorine Escherichia coli	Discharges from MS4 area Major Industrial Point Source
TN05130202007 – 1400	SEVENMILE CREEK	2.4	Nutrients Other Habitat Alteration Escherichia coli	Discharges from MS4 area Hydromodification
TN05130202007 – 1410	SHASTA BRANCH	1.0	Escherichia coli	Discharges from MS4 area
TN05130202007 – 1450	SEVENMILE CREEK	2.0	Nutrients Escherichia coli	Discharges from MS4 area Hydromodification
TN05130202007 – 1500[a]	PAVILLION BRANCH	1.3	Escherichia coli	Discharges from MS4 area
TN05130202007 – 3000	MILL CREEK	5.9	Loss of biological integrity due to siltation Nutrients Low dissolved oxygen Escherichia coli	Collection System Failure Discharges from MS4 area
TN05130202007 – 5000	MILL CREEK	8.1	Nutrients Loss of biological integrity due to siltation Low dissolved oxygen Escherichia coli	Minor Municipal Point Source Livestock in Stream
TN05130202010 – 0200	DRAKES BRANCH	2.7	Escherichia coli	Collection System Failure
TN05130202010 – 0300	DRY FORK	9.9	Escherichia coli	Undetermined Source
TN05130202010 – 0400	EARTHMAN FORK	11.0	Escherichia coli	Undetermined Source
TN05130202010 – 0600	CUMMINGS BRANCH	2.6	Escherichia coli	Livestock in Stream
TN05130202010 – 0700	LITTLE CREEK	1.1	Loss of biological integrity due to siltation Escherichia coli	Land Development Collection System Failure

Table 2 (cont'd). Final 2006 303(d) List for E. coli Impaired Waterbodies – Lower Cumberland Watershed

Waterbody ID	Impacted Waterbody	Miles/Acres Impaired	Cause (Pollutant)	Pollutant Source
TN05130202010 – 0800	EWING CREEK	17.6	Escherichia coli Other Habitat Alterations	Discharges from MS4 area Hydromodification
TN05130202010 – 1000	WHITES CREEK	2.9	Escherichia coli Nutrients	Collection System Failure
TN05130202023 – 0100	EAST FORK BROWN'S CREEK	2.2	Nutrients Other habitat alterations Escherichia coli Oil and Grease	Minor Industrial Point Source Discharges from MS4 area Hydromodification
TN05130202023 – 0300	WEST FORK BROWN'S CREEK	3.6	Nutrients Escherichia coli	Discharges from MS4 area
TN05130202023 – 1000	BROWN'S CREEK	0.2	Nutrients Other Habitat Alterations Escherichia coli Oil and Grease	Minor Industrial Point Source Collection System Failure Discharges from MS4 area Hydromodification
TN05130202023 – 2000	BROWN'S CREEK	4.1	Nutrients Other Habitat Alterations Escherichia coli Oil and Grease	Minor Industrial Point Source Discharges from MS4 area Hydromodification
TN05130202027 – 1000	DRY CREEK	0.5	Escherichia coli	Collection System Failure
TN05130202202 – 1000	PAGES BRANCH	0.6	Escherichia coli	Collection System Failure Discharges from MS4 area
TN05130202202 – 2000	PAGES BRANCH	4.5	Escherichia coli	Discharges from MS4 area
TN05130202209 – 1000	COOPER CREEK	3.9	Other Habitat Alterations Escherichia coli	Discharges from MS4 area
TN05130202212 – 0100	NEELEYS BRANCH	1.7	Escherichia coli	Discharges from MS4 area
TN05130202212 – 1000	GIBSON CREEK	3.7	Habitat loss due to stream flow alteration Other Habitat Alterations Escherichia coli	Discharges from MS4 area Hydromodification

Table 2 (cont'd). Final 2006 303(d) List for E. coli Impaired Waterbodies – Lower Cumberland Watershed

Waterbody ID	Impacted Waterbody	Miles/Acres Impaired	Cause (Pollutant)	Pollutant Source
TN05130202220 – 0100	LUMSLEY FORK	4.7	Escherichia coli	Undetermined Source
TN05130202220 – 0200	WALKERS CREEK	7.8	Escherichia coli	Undetermined Source
TN05130202220 – 0300	SLATERS CREEK	11.3	Loss of biological integrity due to siltation Escherichia coli	Discharges from MS4 area Bank Modification
TN05130202220 – 1000	MANSKERS CREEK	7.9	Loss of biological integrity due to siltation Escherichia coli	Discharges from MS4 area Land Development
TN05130202220 – 2000	MANSKERS CREEK	7.6	Loss of biological integrity due to siltation Escherichia coli	Discharges from MS4 area Land Development
TN05130202314 – 0100[a]	UNNAMED TRIB TO RICHLAND CREEK	1.1	Escherichia coli	Discharges from MS4 area
TN05130202314 – 0200 [a]	MURPHY ROAD BRANCH	1.5	Escherichia coli	Discharges from MS4 area
TN05130202314 – 0300	BOSLEY SPRINGS BRANCH	1.5	Other Habitat Alterations Escherichia coli	Discharges from MS4 area Hydromodification
TN05130202314 – 0400	SUGARTREE CREEK	4.3	Nutrients Other Habitat Alterations Escherichia coli	Discharges from MS4 area Hydromodification
TN05130202314 – 0700	VAUGHNS GAP BRANCH	0.6	Other Habitat Alterations Escherichia coli	Collection System Failure Hydromodification
TN05130202314 – 0750	VAUGHNS GAP BRANCH	1.9	Other Habitat Alterations Escherichia coli	Discharges from MS4 area Hydromodification
TN05130202314 – 0800	JOCELYN HOLLOW BRANCH	2.0	Escherichia coli	Discharges from MS4 area
TN05130202314 – 1000	RICHLAND CREEK	1.9	Escherichia coli Other Habitat Alterations	Collection System Failure Hydromodification
TN05130202314 – 2000	RICHLAND CREEK	6.7	Escherichia coli Other Habitat Alterations	Collection System Failure Hydromodification
TN05130202314 – 3000	RICHLAND CREEK	4.0	Nutrients Other Habitat Alterations Escherichia coli	Collection System Failure Discharges from MS4 area Hydromodification

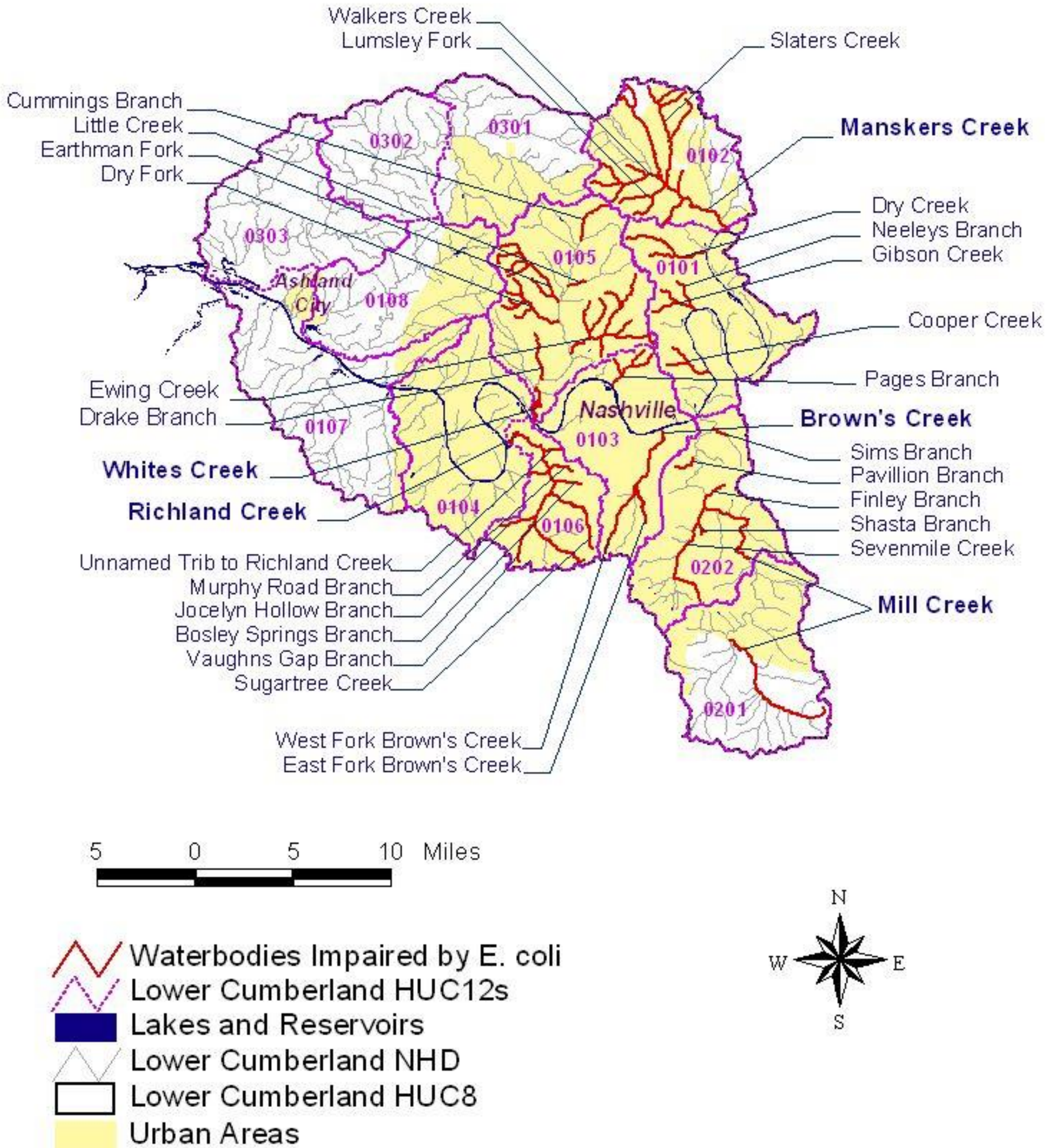

Figure 4. Waterbodies Impaired by E. Coli (as Documented on the Final 2006 303(d) List).

6.0 WATER QUALITY ASSESSMENT AND DEVIATION FROM TARGET

There are multiple water quality monitoring stations that provide data for waterbodies identified as impaired for E. coli in the Lower Cumberland watershed. Monitoring stations located on high quality waters have been italicized:

- HUC-12 05130202_0101:
  - COOPE000.1DA – Cooper Creek, at McGinnis Rd.
  - GIBSO001.7DA – Gibson Creek, at Saunders Rd.
  - GIBSO002.1DA – Gibson Creek, at Graycroft Rd.
  - NEELE000.45DA – Neeleys Branch, at Madison Blvd.
  - NEELE001.0DA – Neeleys Branch, at Maple St.
  - NEELE001.45DA – Neeleys Branch, at Williams Rd.
  - DRY000.3DA – Dry Creek, at Myatt Dr.
  - DRY001.1DA – Dry Creek, at Gallatin Rd.
- HUC-12 05130202_0102:
  - LUMSL000.1DA – Lumsley Fork, at Brick Church Pike & Hitt Lane
  - *MANSK000.8SR – Manskers Creek, at Gallatin Pike*
  - *MANSK002.8SR – Manskers Creek, at Caldwell Dr., off Long Hollow Pike, behind Kroger*
  - *MANSK004.7SR – Manskers Creek, at Old Stone Bridge Rd.*
  - MANSK006.2SR – Manskers Creek, u/s Bakers Fork
  - MANSK008.5SR – Manskers Creek, at Old Shiloh Rd.
  - SLATE000.3SR – Slaters Creek, off Highway 31W
  - WALKE000.2DA – Walkers Creek, at Lickton Pike
- HUC-12 05130202_0103:
  - PAGES0000.1DA – Pages Branch, at Whites Creek Pike
  - PAGES0001.0DA – Pages Branch, at Trinity lane
  - PAGES0002.0DA – Pages Branch, at Jones Rd.
  - BROWN000.1DA – Brown's Creek, at Visco Dr.
  - BROWN000.4DA – Brown's Creek, off Fessler's Lane
  - BROWN002.9DA – Brown's Creek, at state fairgrounds, u/s usgs gage
  - BROWN003.3DA – Brown's Creek, at Bransford Ave.
  - EFBRO000.2DA – East Fork Brown's Creek, at Berry Rd.
  - WFBRO000.1DA – West Fork Brown's Creek, at Park Terrace

- HUC-12 05130202_0105:
  - DRY000.4DA – Dry Fork, at Dry Fork Rd.
  - DRAKE000.2DA – Drakes Branch, at West Hamilton Rd.
  - CUMMI000.4DA – Cummings Branch, at Scott Rd.
  - EARTH000.1DA – Earthman Fork, at Knight Rd.
  - *EWING000.8DA – Ewing Creek, at Whites Creek Pike*
  - *EWING001.4DA – Ewing Creek, at Knight Dr.*
  - *EWING002.4DA – Ewing Creek, at Ewing Ln.*
  - *EWING003.7DA – Ewing Creek, at Brick Church Pike*
  - LITTL001.2DA – Little Creek, off Old Hickory Blvd.
  - WHITE000.7DA – Whites Creek, at County Hospital Rd.
- HUC-12 05130202_0106:
  - *JHOLL000.1DA – Jocelyn Hollow Branch, at confluence with Richland Creek*
  - *JHOLL000.2DA – Jocelyn Hollow Branch, at Post Rd.*
  - MROAD000.2DA – Murphy Road Branch, off Colorado
  - RICHL001.4DA – Richland Creek, at quarry sewer crossing
  - RICHL002.2DA – Richland Creek, at West Park
  - RICHL003.2DA – Richland Creek, at Urbandale
  - *RICHL004.2DA – Richland Creek, at Knob Rd.*
  - *RICHL006.8DA – Richland Creek, off West End Ave.*
  - *RICHL007.2DA – Richland Creek, at West Tyne Blvd.*
  - *RICHL008.9DA – Richland Creek, at Belle Meade Blvd.*
  - RICHL0T0.1DA – unnamed tributary, north of I-40, at Morrow Rd.
  - RICHL1T0.4DA – Bosley Springs Branch, at Bosley Springs Rd.
  - SUGAR000.1DA – Sugartree Creek, at Harding Rd., in West End, by Kroger
  - SUGAR000.9DA – Sugartree Creek, at Estes Lane & Woodmont Blvd.
  - SUGAR002.2DA – Sugartree Creek, at Hobbs Rd.
  - *VGAP000.2DA – Vaughns Gap Branch, at Harding Place*
- HUC-12 05130202_0201:
  - *MILL021.2DA – Mill Creek, u/s Concord Rd.*
  - *MILL022.2WI – MillCreek, at Sunset Rd.*
- HUC-12 05130202_0202:
  - FINLE000.1DA – Finley Branch, at Curry Rd.
  - *MILL009.8DA – Mill Creek, at Harding Pike*
  - *MILL011.0DA – Mill Creek, u/s Franklin-Limestone Rd.*
  - *MILL012.4DA – Mill Creek, 300 yds u/s Antioch Pike*
  - PAVIL000.1DA – Pavillion Branch, at Wilhagen Rd.
  - *SEVEN000.2DA – Sevenmile Creek, at McCall St. & Antioch Pike*

- *SEVEN003.8DA – Sevenmile Creek, at Ellington Ag. Center*
- *SEVEN004.5DA – Sevenmile Creek, first unnamed trib u/s entrance to Players*
- *SEVEN004.6DA – Sevenmile Creek, second unnamed trib u/s entrance to Players*
- SHAST000.3DA – Shasta Branch, at Paragon Mills Rd. and Benita Dr.
- *SIMS000.8DA – Sims Branch, at Elm Hill Pike*

The locations of these monitoring stations is shown in Figures 5 thru 7. Water quality monitoring results for these stations are tabulated in Appendix B. Examination of the data shows exceedances of the 487 CFU/100 mL (lakes, reservoirs, State Scenic Rivers, or Tier II or Tier III waterbodies) and 941 CFU/100 mL (all other waterbodies) maximum E. coli standard at many monitoring stations. Water quality monitoring results for those stations with 10% or more of samples exceeding water quality maximum criteria are summarized in Table 3.

Several of the water quality monitoring stations (Table 3 and Appendix B) have at least one E. coli sample value reported as >2400. In addition, at nine of these sites, the maximum E. coli sample value is >2400. For the purpose of calculating summary data statistics, TMDLs, Waste Load Allocations (WLAs), and Load Allocations (LAs), these data values are treated as (equal to) 2400. Therefore, the calculated results are considered to be estimates. Future E. coli sample analyses at these sites should follow established protocol. See Section 9.4.

There were not enough data to calculate the geometric mean at each monitoring station. Whenever a minimum of 5 samples was collected at a given monitoring station over a period of not more than 30 consecutive days, a geometric mean analysis is conducted.

Note that several waterbodies have been divided into multiple segments and are represented by multiple water quality monitoring stations. The two impaired segments of Mill Creek are represented by five water quality monitoring stations. The monitoring stations at miles 9.8, 11.0, and 12.4 are located in segment 007-3000 (from Briley Parkway to Whittemore Branch near Antioch). The monitoring stations at miles 21.2, and 22.2 are located in segment 007-5000 (from Owl Creek to headwaters). The two impaired segments of Sevenmile Creek are represented by four water quality monitoring stations. The monitoring station at mile 0.2 is located in segment 007-1400 (from Mill Creek to Nolensville Road). The monitoring stations at miles 3.8, 4.5, and 4.6 are located in segment 007-1450 (from Nolensville Road to Brentwood Creek).

The two segments of Little Creek are represented by one water quality monitoring station. There are no monitoring stations located in segment 010-0700 (from Whites Creek to I-24), which is listed as impaired. The monitoring station at mile 1.2 is located in segment 010-0750 (from I-24 to the headwaters), which is not listed as impaired.

The two impaired segments of Brown’s Creek are represented by four water quality monitoring stations. The monitoring station at mile 0.1 is located in segment 023-1000 (from Cheatham Reservoir to Visco Drive). The monitoring stations at miles 0.4, 2.9, and 3.3 are located in segment 023-2000 (from Visco Drive to the headwaters).

The impaired segment of Dry Creek is represented by two water quality monitoring stations. The monitoring stations at miles 0.3 and 1.1 are located in segment 027-1000 (from Cheatham Reservoir to the railroad bridge).

The two impaired segments of Pages Branch are represented by three water quality monitoring stations. The monitoring station at mile 0.1 is located in segment 202-1000 (from Cheatham Reservoir to I-65). The monitoring stations at miles 1.0 and 2.0 are located in segment 202-2000 (from I-65 to the headwaters).

The two impaired segments of Manskers Creek are represented by five water quality monitoring stations. The monitoring stations at miles 0.8, 2.8, and 4.7 are located in segment 220-1000 (from Cheatham Reservoir to Slaters Creek). The monitoring stations at miles 6.2 and 8.5 are located in segment 220-2000 (from Slaters Creek to the headwaters).

The three impaired segments of Richland Creek are represented by seven water quality monitoring stations. The monitoring stations at miles 1.4, 2.2, and 3.2 are located in segment 314-1000 (from Cheatham Reservoir to Briley Parkway near West Park). The monitoring stations at miles 4.2 and 6.8 are located in segment 314-2000 (from West Park to Jocelyn Hollow Branch). The monitoring stations at miles 7.2 and 8.9 are located in segment 314-3000 (from Jocelyn Hollow Branch to the headwaters).

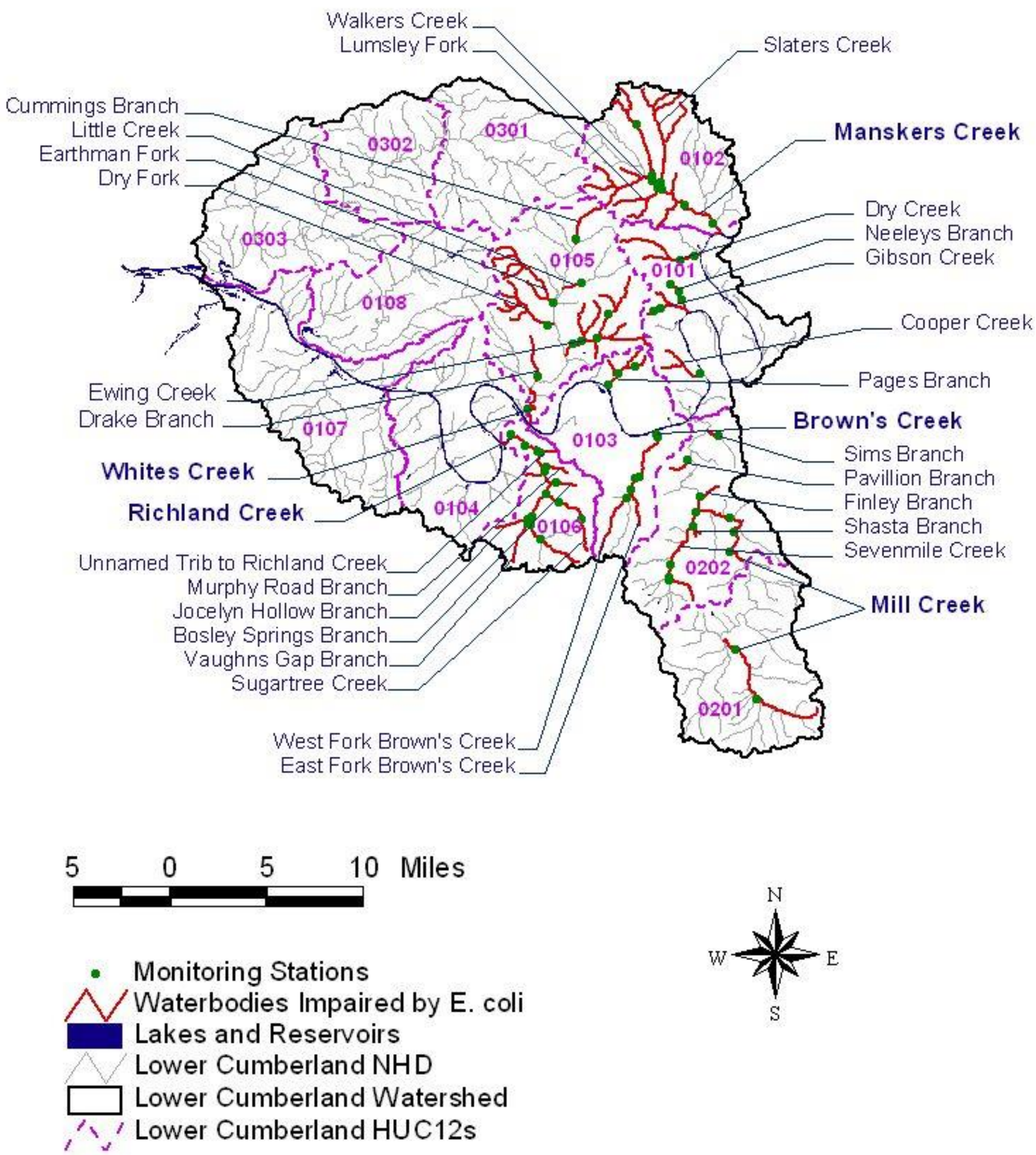

Figure 5. Overview of Water Quality Monitoring Stations in the Lower Cumberland Watershed

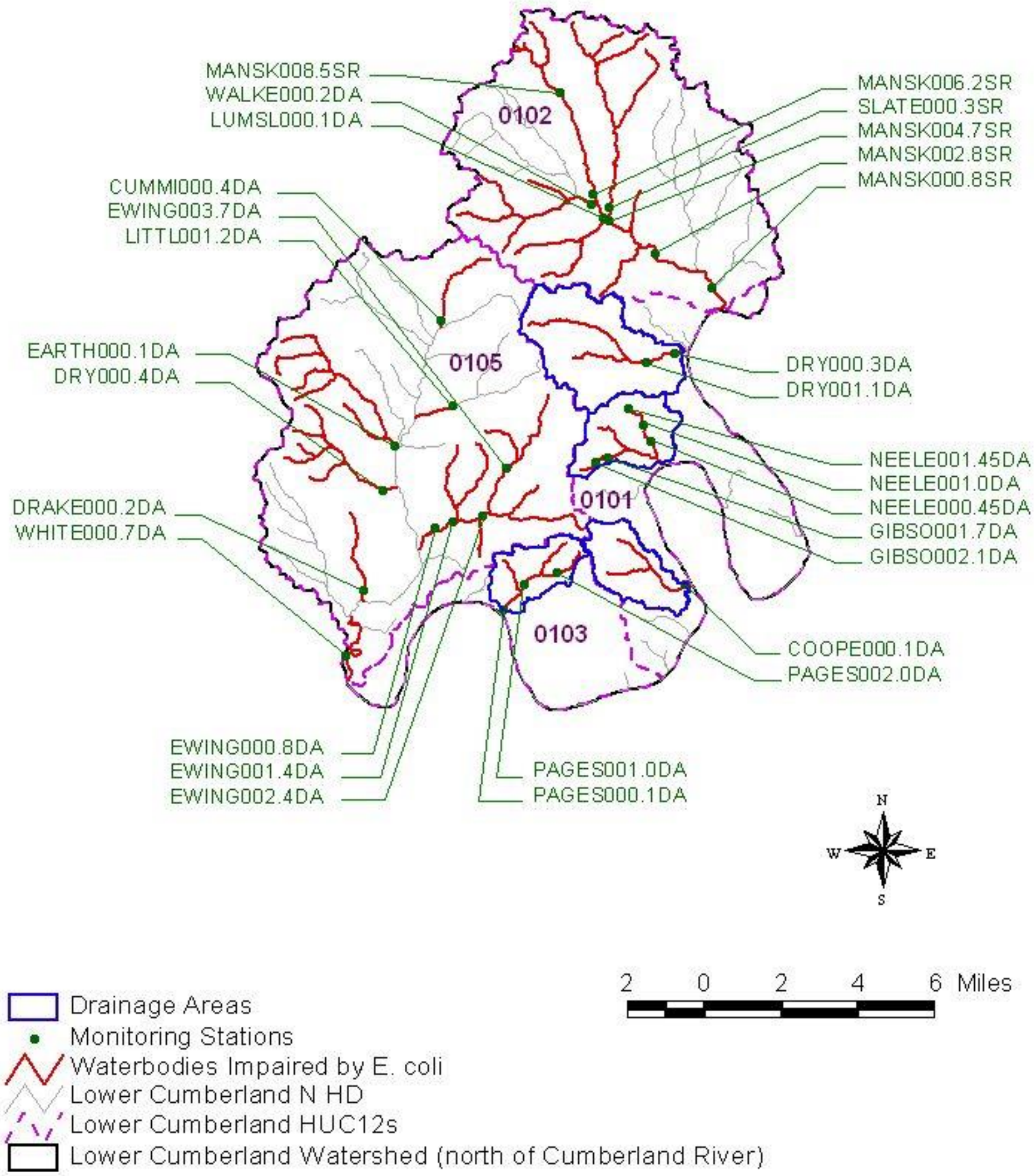

Figure 6. Water Quality Monitoring Stations in the Lower Cumberland Watershed (monitoring stations north of the Cumberland River)

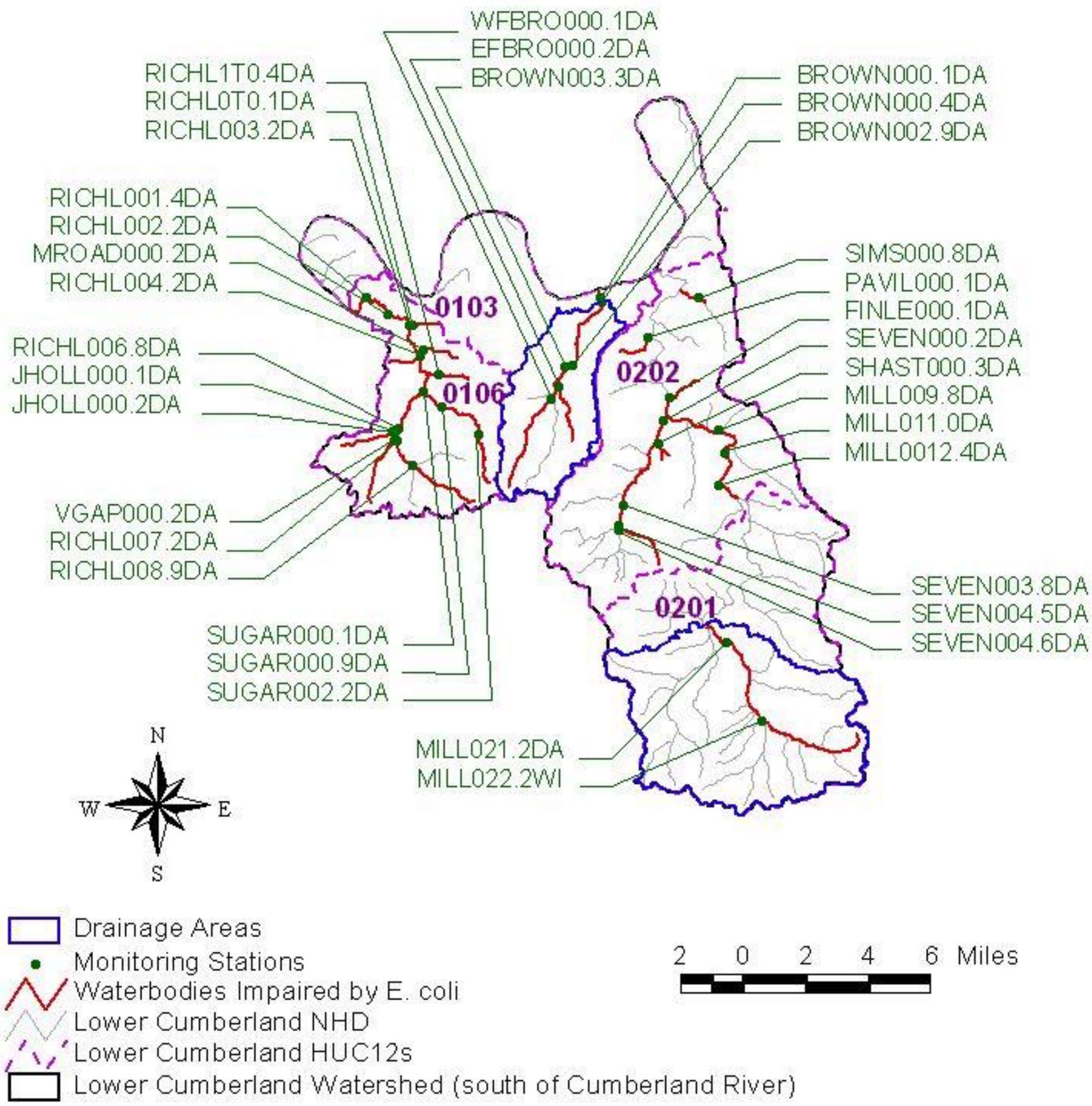

Figure 7. Water Quality Monitoring Stations in the Lower Cumberland Watershed
(monitoring stations south of the Cumberland River)

Table 3 Summary of Water Quality Monitoring Data

Monitoring Station	Date Range	E. Coli (Max WQ Target = 941 CFU/100 mL)**				
		Data Pts.	Min. [CFU/100 ml]	Avg. [CFU/100 ml]	Max. [CFU/100 ml]	No. Exceed. WQ Max. Target
BROWN000.1DA	2001 – 2005	20	44	597	2,400	4
BROWN000.4DA	2001 – 2006	13	46	549	>2,400	3
BROWN002.9DA	2005 – 2006	7	86	399	1600	1
BROWN003.3DA	2001 – 2005	27	20	384	2,401	3
DRY000.3DA	2000 – 2005	34	1	867	4,900	10
DRY001.1DA	2000 – 2005	31	25	441	2,419	4
EFBRO000.2DA	2001 – 2006	38	14	663	2,401	9
EWING000.8DA	*2001 – 2006*	*18*	*4*	*485*	*>2,400*	*4*
EWING001.4DA	*2002 – 2005*	*18*	*22*	*665*	*3,400*	*5*
EWING002.4DA	*2002 – 2005*	*17*	*90*	*744*	*3,400*	*7*
EWING003.7DA	*2002 – 2005*	*18*	*20*	*1,043*	*5,700*	*8*
FINLE000.1DA	2001 – 2006	20	23	671	>2,400	6
GIBSO001.7DA	2000 – 2004	28	13	474	2,000	5
JHOLL000.1DA	*2002 – 2005*	*18*	*4*	*1,968*	*9,500*	*13*
JHOLL000.2DA	*2002 – 2006*	*37*	*17*	*772*	*4,200*	*17*
LITTL001.2DA	2002 – 2006	14	9	448	2,400	3
MANSK002.8SR	*2001 – 2006*	*15*	*16*	*487*	*2,900*	*6*
MANSK004.7SR	*2001 – 2004*	*12*	*18*	*253*	*580*	*3*
MANSK006.2SR	2001 – 2006	17	24	560	>2,400	2
MANSK008.5SR	2001 – 2004	10	14	234	980	1
MILL011.0DA	*2001 – 2006*	*28*	*8*	*322*	*>2,400*	*4*
MILL022.2WI	*2001 – 2006*	*14*	*39*	*2167*	*>2,4000*	*4*
NEELE000.45DA	2000 – 2005	46	29	1,787	24,001	22
NEELE001.0DA	2001 – 2005	39	1	888	4,900	10
PAGES000.1DA	2000 – 2004	16	1	326	2,401	2
PAGES001.0DA	2000 – 2004	17	32	337	1,100	2

Table 3 (cont'd) Summary of Water Quality Monitoring Data

Monitoring Station	Date Range	E. Coli (Max WQ Target = 941 CFU/100 mL)**				
		Data Pts.	Min. [CFU/100 ml]	Avg. [CFU/100 ml]	Max. [CFU/100 ml]	No. Exceed. WQ Max. Target
PAGES002.0DA	2000 – 2002	9	10	584	3,700	1
PAVIL000.1DA	2003 – 2004	7	460	5,419	32,001	3
RICHL001.4DA	2001 – 2005	21	40	654	3,300	4
RICHL002.2DA	2001 – 2006	17	43	485	2,400	2
RICHL003.2DA	2001 – 2005	30	56	1,051	4,800	12
RICHL004.2DA	2002 – 2005	18	13	1,022	3,500	9
RICHL006.8DA	*2001 – 2006*	*23*	*25*	*467*	*2,400*	*4*
RICHL007.2DA	*2001 –2005*	*19*	*8*	*209*	*870*	*2*
RICHL008.9DA	*2004 – 2006*	*15*	*93*	*338*	*1,400*	*3*
RICHL0T0.1DA	2002 – 2004	8	43	554	2,000	2
RICHL1T0.4DA	2003 – 2006	12	16	1,360	>2,400	7
SEVEN000.2DA	*2001 – 2006*	*41*	*21*	*737*	*2,700*	*19*
SEVEN003.8DA	*2001 – 2006*	*15*	*77*	*553*	*>2,400*	*6*
SEVEN004.5DA	*2002 – 2005*	*17*	*24*	*862*	*3,800*	*7*
SEVEN004.6DA	*2005 – 2005*	*17*	*30*	*698*	*4,200*	*8*
SHAST000.3DA	2002 – 2003	10	78	450	2,400	1
SIMS000.8DA	*2001 – 2006*	*20*	*43*	*314*	*1,400*	*2*
SLATE000.3SR	2001 – 2006	16	8	732	4,600	3
SUGAR000.1DA	2002 – 2005	42	3	549	3,600	7
SUGAR000.9DA	2004 – 2006	4	22	2,210	8,200	1
SUGAR002.2DA	2002 – 2005	21	0	1,094	4,200	10
VGAP000.2DA	*2002 – 2006*	*27*	*16*	*615*	*3,900*	*8*
WALKE000.2DA	2001 – 2004	12	20	291	1,200	1
WFBRO000.1DA	2001 – 2006	39	16	661	>2,400	11

** Instantaneous maximum water quality target is 487 CFU/100 mL for lakes, reservoirs, State Scenic Rivers, Tier II and Tier III waterbodies and 941 CFU/100 mL for other waterbodies. Waterbodies utilizing the 487 CFU/100 mL target are italicized.

7.0 SOURCE ASSESSMENT

An important part of TMDL analysis is the identification of individual sources, or source categories of pollutants in the watershed that affect pathogen loading and the amount of loading contributed by each of these sources.

Under the Clean Water Act, sources are classified as either point or nonpoint sources. Under 40 CFR §122.2, (http://www.epa.gov/epacfr40/chapt-I.info/chi-toc.htm), a point source is defined as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. The National Pollutant Discharge Elimination System (NPDES) program (http://cfpub1.epa.gov/npdes/index.cfm) regulates point source discharges. Point sources can be described by three broad categories: 1) NPDES regulated municipal (http://cfpub1.epa.gov/npdes/home.cfm?program_id=13) and industrial (http://cfpub1.epa.gov/npdes/home.dfm?program_id=14) wastewater treatment facilities (WWTFs); 2) NPDES regulated industrial and municipal storm water discharges (http://cfpub1.epa.gov/npdes/home.cfm?program_id=6); and 3) NPDES regulated Concentrated Animal Feeding Operations (CAFOs) (http://cfpub1.epa.gov/npdes/home.cfm?program_id=7)). A TMDL must provide Waste Load Allocations (WLAs) for all NPDES regulated point sources. Nonpoint sources are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. For the purposes of this TMDL, all sources of pollutant loading not regulated by NPDES permits are considered nonpoint sources. The TMDL must provide a Load Allocation (LA) for these sources.

7.1 Point Sources

7.1.1 NPDES Regulated Municipal and Industrial Wastewater Treatment Facilities

Both treated and untreated sanitary wastewater contain coliform bacteria. There are 4 WWTFs in the Lower Cumberland Watershed that have NPDES permits authorizing the discharge of treated sanitary wastewater. All of these facilities are located in impaired subwatersheds or drainage areas (see Table 4 & Figure 8), but the discharges are to unimpaired waterbodies. The permit limits for discharges from these WWTFs are in accordance with the coliform criteria specified in Tennessee Water Quality Standards for the protection of the recreation use classification.

Non-permitted point sources of (potential) E. coli contamination of surface waters associated with STP collection systems include leaking collection systems (LCSs) and sanitary sewer overflows (SSOs).

> *Note: As stated in Section 5.0, the current coliform criteria are expressed in terms of E. coli concentration, whereas previous criteria were expressed in terms of fecal coliform and E. coli concentration. Due to differences in permit issuance dates, some permits still have fecal coliform limits instead of E. coli. As permits are reissued, limits for fecal coliform will be replaced by E. coli limits.*

Table 4 NPDES Permitted WWTFs in Impaired Subwatersheds or Drainage Areas

NPDES Permit No.	Facility	Design Flow [MGD]	Receiving Stream
TN0024970	Nashville Whites Creek STP	37.5	Cumberland River at Mile 182.6
TN0020575	Nashville Central STP	100	Cumberland River at Mile 189.2
TN0020648	Nashville Dry Creek STP	24	Cumberland River at Mile 213.9
TN0058106	Hendersonville Shopping Center	0.02	Unnamed Tributary at Mile 0.6 to Cumberland River at Mile 215.6

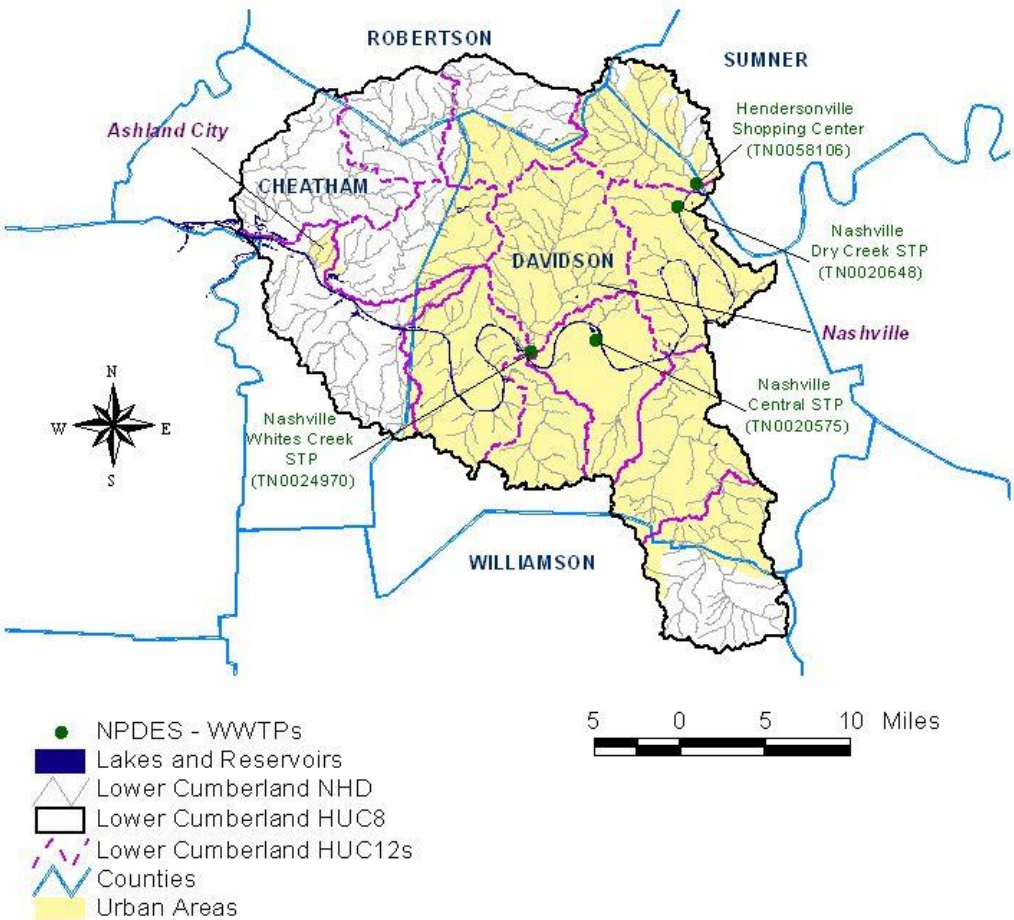

Figure 8. NPDES Regulated Point Sources in and near Impaired Subwatersheds and Drainage Areas of the Lower Cumberland Watershed.

7.1.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

Municipal Separate Storm Sewer Systems (MS4s) are considered to be point sources of E. coli. Discharges from MS4s occur in response to storm events through road drainage systems, curb and gutter systems, ditches, and storm drains. Phase I of the EPA storm water program (http://cfpub.epa.gov/npdes/stormwater/swphases.cfm#phase1) requires large and medium MS4s to obtain NPDES storm water permits. Large and medium MS4s are those located in incorporated places or counties serving populations greater than 100,000 people. At present, Nashville/Davidson County is the only large or medium (Phase I) MS4 in the Lower Cumberland Watershed.

Metro Nashville/Davidson County is currently operating under TDEC Order No. 88-3364 and Supplemental TDEC Order No. 99-0390. As part of compliance with the Commissioner's Orders, Metro Water and Sewer initiated the Nashville Overflow Abatement Program in 1990. Over 137 projects have been successfully completed. 61 of the most critical overflow points in the sanitary system have been eliminated, separate sanitary overflows (SSOs) have been reduced by 67%, pump station overflows have been reduced by 91%, and CSO system overflow points have been reduced from 31 to 11. Future efforts will be directed toward rehabilitation and recapturing system capacity through I/I elimination. Information regarding the Nashville Overflow Abatement Program (OAP) may be obtained from the OAP website at:

http://www.nashvilleoap.com/.

As of March 2003, regulated small MS4s in Tennessee must also obtain NPDES permits in accordance with the Phase II storm water program (http://cfpub.epa.gov/npdes/stormwater/swphases.cfm#phase2). A small MS4 is designated as *regulated* if: a) it is located within the boundaries of a defined urbanized area that has a residential population of at least 50,000 people and an overall population density of 1,000 people per square mile; b) it is located outside of an urbanized area but within a jurisdiction with a population of at least 10,000 people, a population density of 1,000 people per square mile, and has the potential to cause an adverse impact on water quality; or c) it is located outside of an urbanized area but contributes substantially to the pollutant loadings of a physically interconnected MS4 regulated by the NPDES storm water program. Most regulated small MS4s in Tennessee obtain coverage under the *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems* (http://state.tn.us/environment/wpc/ppo/TN%20Small%20MS4%20Modified%20General%20Permit%202003.pdf) (TDEC, 2003).). Belle Meade, Berry Hill, Brentwood, Forest Hills, Goodlettsville, Hendersonville, Millersville, Nolensville, Oak Hill, Cheatham County, Sumner County, and Williamson County are covered under Phase II of the NPDES Storm Water Program.

The Tennessee Department of Transportation (TDOT) has been issued an individual MS4 permit (TNS077585) that authorizes discharges of storm water runoff from State roads and interstate highway right-of-ways that TDOT owns or maintains, discharges of storm water runoff from TDOT owned or operated facilities, and certain specified non-storm water discharges. This permit covers all eligible TDOT discharges statewide, including those located outside of urbanized areas. TDOT's individual MS4 permit may be obtained from the Tennessee Department of Environment and Conservation (TDEC) website: http://state.tn.us/environment/wpc/stormh2o/TNS077585.pdf .

For information regarding storm water permitting in Tennessee, see the TDEC website:

http://www.state.tn.us/environment/wpc/stormh2o/.

7.1.3 NPDES Concentrated Animal Feeding Operations (CAFOs)

Animal feeding operations (AFOs) are agricultural enterprises where animals are kept and raised in confined situations. AFOs congregate animals, feed, manure and urine, dead animals, and production operations on a small land area. Feed is brought to the animals rather than the animals grazing or otherwise seeking feed in pastures, fields, or on rangeland (USEPA, 2002a). Concentrated Animal Feeding Operations (CAFOs) are AFOs that meet certain criteria with respect to animal type, number of animals, and type of manure management system. CAFOs are considered to be potential point sources of pathogen loading and are required to obtain an NPDES permit. Most CAFOs in Tennessee obtain coverage under TNA000000, *Class II Concentrated Animal Feeding Operation General Permit* (http://state.tn.us/environment/wpc/ppo/CAFO%20Final%20PDF%20Modified.pdf), while larger, Class I CAFOs are required to obtain an individual NPDES permit.

As of November 26, 2007, there are no Class II CAFOs with coverage under the general NPDES permit and no Class I CAFOs with an individual permit located in the Lower Cumberland Watershed.

7.2 Nonpoint Sources

Nonpoint sources of coliform bacteria are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. These sources generally, but not always, involve accumulation of coliform bacteria on land surfaces and wash off as a result of storm events. Nonpoint sources of E. coli loading are primarily associated with agricultural and urban land uses. The vast majority of waterbodies identified on the Final 2006 303(d) List as impaired due to E. coli are attributed to nonpoint agricultural or urban sources.

7.2.1 Wildlife

Wildlife deposit coliform bacteria, with their feces, onto land surfaces where it can be transported during storm events to nearby streams. The overall deer density for Tennessee was estimated by the Tennessee Wildlife Resources Agency (TWRA) to be 23 animals per square mile.

7.2.2 Agricultural Animals

Agricultural activities can be a significant source of coliform bacteria loading to surface waters. The activities of greatest concern are typically those associated with livestock operations:

- Agricultural livestock grazing in pastures deposit manure containing coliform bacteria onto land surfaces. This material accumulates during periods of dry weather and is available for washoff and transport to surface waters during storm events. The number of animals in pasture and the time spent grazing are important factors in determining the loading contribution.
- Processed agricultural manure from confined feeding operations is often applied to land surfaces and can provide a significant source of coliform bacteria loading. Guidance for issues relating to manure application is available through the University of Tennessee Agricultural Extension Service and the Natural Resources Conservation Service (NRCS).

- Agricultural livestock and other unconfined animals often have direct access to waterbodies and can provide a concentrated source of coliform bacteria loading directly to a stream.

Data sources related to livestock operations include the 2002 Census of Agriculture (http://www.nass.usda.gov/census/census02/volume1/tn/index2.htm). Livestock data for counties located within the Lower Cumberland watershed are summarized in Table 5. Note that, due to confidentiality issues, any tabulated item that identifies data reported by a respondent or allows a respondent's data to be accurately estimated or derived is suppressed and coded with a 'D' (USDA, 2004).

Table 5 Livestock Distribution in the Lower Cumberland Watershed

County	Livestock Population (2002 Census of Agriculture)						
	Beef Cow	Milk Cow	Poultry		Hogs	Sheep	Horse
			Layers	Broilers			
Cheatham	5,722	6	747	12	523	30	1,035
Davidson	D	D	932	0	7	4	1,254
Robertson	21,627	2,493	1,886	270	3,969	269	2,439
Sumner	22,246	884	1,451	336	592	537	3,590
Williamson	22,761	765	1,485	179	990	969	5,331

* In keeping with the provisions of Title 7 of the United States Code, no data are published in the 2002 Census of Agriculture that would disclose information about the operations of an individual farm or ranch. Any tabulated item that identifies data reported by a respondent or allows a respondent's data to be accurately estimated or derived is suppressed and coded with a 'D' (USDA, 2004).

7.2.3 Failing Septic Systems

Some coliform loading in the Lower Cumberland watershed can be attributed to failure of septic systems and illicit discharges of raw sewage. Estimates from 1997 county census data of people in the Lower Cumberland watershed utilizing septic systems were compiled using the WCS and are summarized in Table 6. In middle and eastern Tennessee, it is estimated that there are approximately 2.37 people per household on septic systems, some of which can be reasonably assumed to be failing. As with livestock in streams, discharges of raw sewage provide a concentrated source of coliform bacteria directly to waterbodies.

7.2.4 Urban Development

Nonpoint source loading of coliform bacteria from urban land use areas is attributable to multiple sources. These include: stormwater runoff, illicit discharges of sanitary waste, runoff from improper disposal of waste materials, leaking septic systems, and domestic animals. Impervious surfaces in urban areas allow runoff to be conveyed to streams quickly, without interaction with soils and groundwater. Urban land use area in impaired subwatersheds in the Lower Cumberland Watershed ranges from 1.7% to 68.7%. Land use for the Lower Cumberland impaired drainage areas is summarized in Figures 9 through 12 and tabulated in Appendix A.

Table 6 Estimated Population on Septic Systems in the Lower Cumberland Watershed

County	Total Population (2000 Census)	Population on Septic Systems
Cheatham	35,912	699
Davidson	569,891	40,090
Robertson	54,433	1,291
Sumner	130,449	10,899
Williamson	126,638	7,388

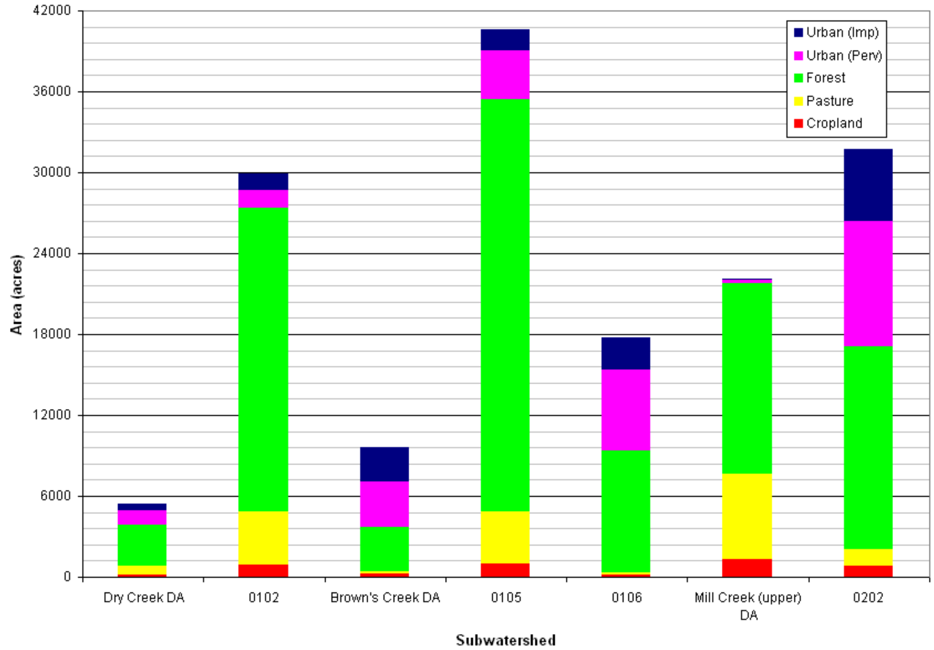

Figure 9. Land Use Area of Lower Cumberland E. coli-Impaired Subwatersheds – Drainage Areas Greater Than 5,000 Acres

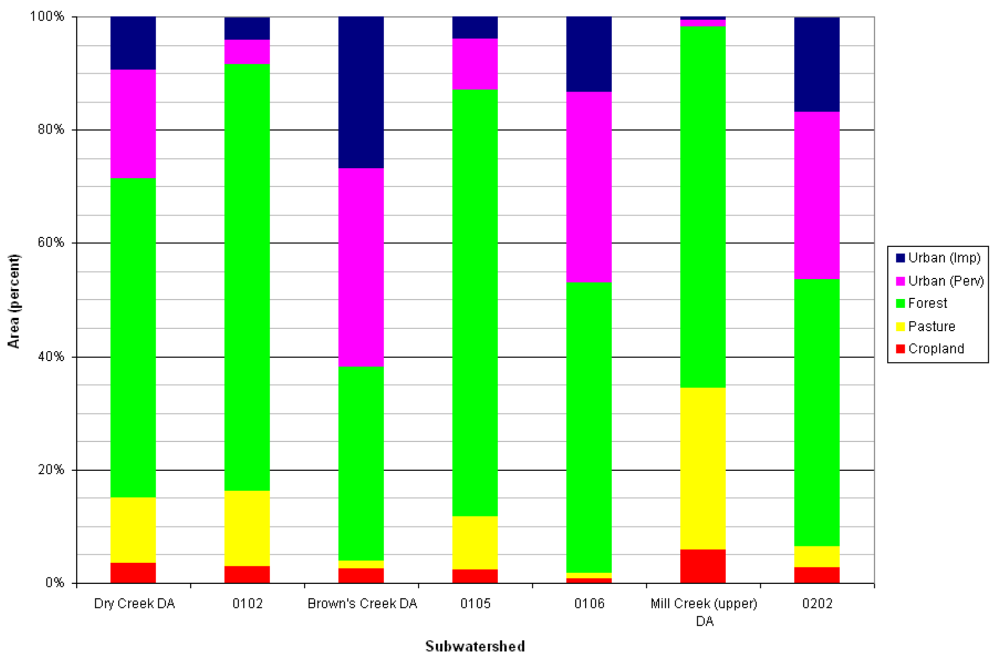

Figure 10. Land Use Percent of the Lower Cumberland E. coli-Impaired Subwatersheds – Drainage Areas Greater Than 5,000 Acres

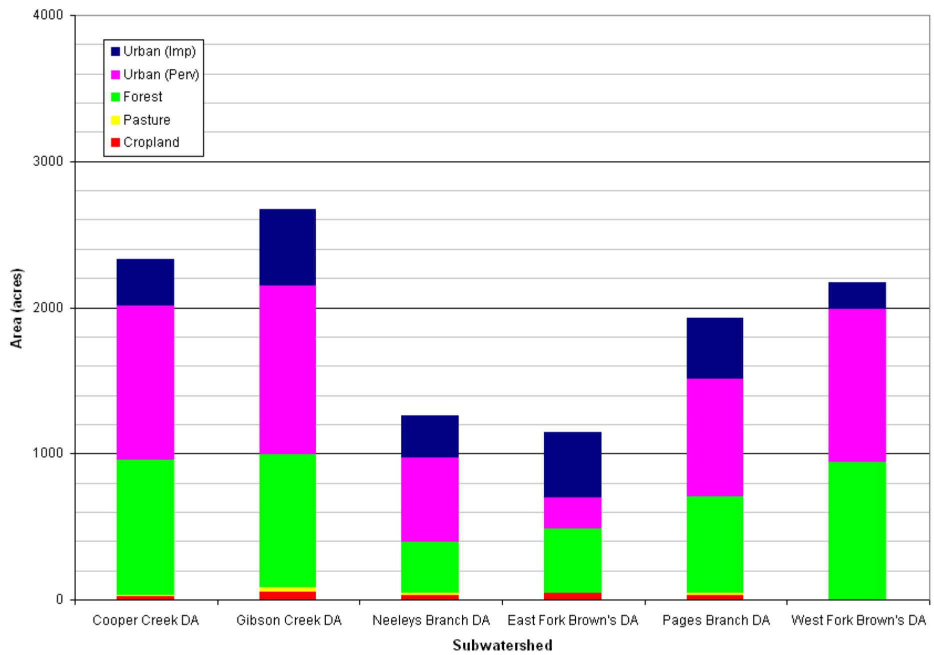

Figure 11. Land Use Area of Lower Cumberland E. coli-Impaired Subwatersheds – Drainage Areas Less Than 5,000 Acres

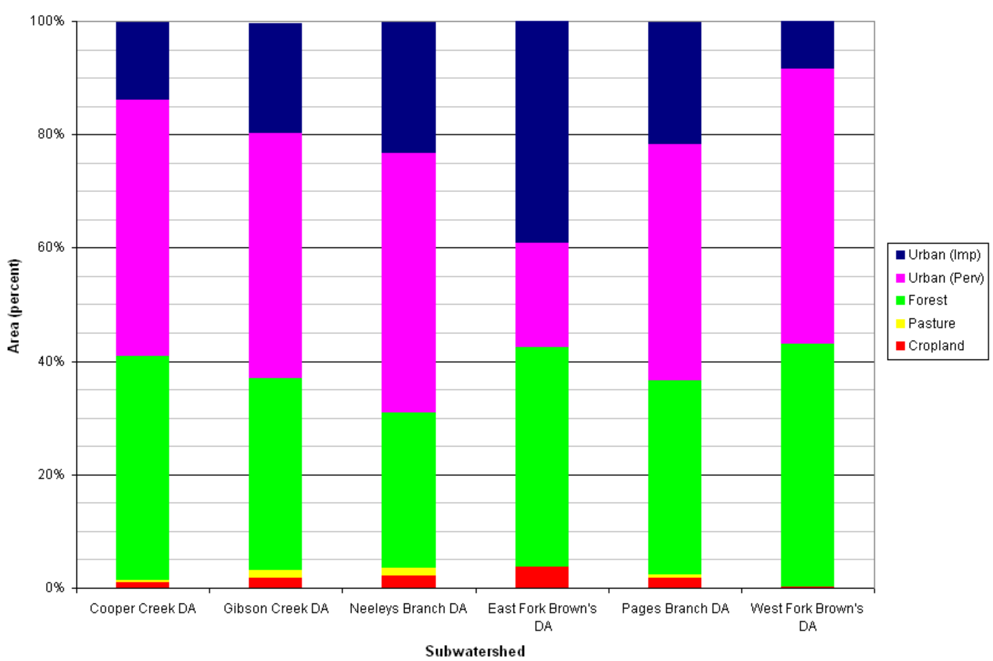

Figure 12. Land Use Percent of the Lower Cumberland E. coli-Impaired Subwatersheds – Drainage Areas Less Than 5,000 Acres

8.0 DEVELOPMENT OF TOTAL MAXIMUM DAILY LOADS

The Total Maximum Daily Load (TMDL) process quantifies the amount of a pollutant that can be assimilated in a waterbody, identifies the sources of the pollutant, and recommends regulatory or other actions to be taken to achieve compliance with applicable water quality standards based on the relationship between pollution sources and in-stream water quality conditions. A TMDL can be expressed as the sum of all point source loads (Waste Load Allocations), non-point source loads (Load Allocations), and an appropriate margin of safety (MOS) that takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$\text{TMDL} = \Sigma\ \text{WLAs} + \Sigma\ \text{LAs} + \text{MOS}$$

The objective of a TMDL is to allocate loads among all of the known pollutant sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. 40 CFR §130.2 (i) (http://www.epa.gov/epacfr40/chapt-I.info/chi-toc.htm) states that TMDLs can be expressed in terms of mass per time, toxicity, or <u>other appropriate measure</u>.

This document describes TMDL, Waste Load Allocation (WLA), Load Allocation (LA), and Margin of Safety (MOS) development for waterbodies identified as impaired due to E. coli on the Final 2006 303(d) list.

8.1 Expression of TMDLs, WLAs, & LAs

In this document, the E. coli TMDL is a daily load expressed as a function of mean daily flow (daily loading function). For implementation purposes, corresponding percent load reduction goals (PLRGs) to decrease E. coli loads to TMDL target levels, within each respective flow zone, are also expressed. WLAs & LAs for precipitation-induced loading sources are also expressed as daily loading functions in CFU/day/acre. Allocations for loading that is independent of precipitation (WLAs for WWTFs and LAs for “other direct sources”) are expressed as CFU/day.

8.2 Area Basis for TMDL Analysis

The primary area unit of analysis for TMDL development was the HUC-12 subwatershed containing one or more waterbodies assessed as impaired due to E. coli (as documented on the Final 2006 303(d) List). In some cases, however, TMDLs were developed for an impaired waterbody drainage area only. Determination of the appropriate area to use for analysis (see Table 7) was based on a careful consideration of a number of relevant factors, including: 1) location of impaired waterbodies in the HUC-12 subwatershed; 2) land use type and distribution; 3) water quality monitoring data; and 4) the assessment status of other waterbodies in the HUC-12 subwatershed.

Table 7 Determination of Analysis Areas for TMDL Development

HUC-12 Subwatershed (05130202____)	Impaired Waterbody	Area
0101	Cooper Creek Dry Creek Gibson Creek Neeleys Branch	DA
0102	Lumsley Fork Manskers Creek Slaters Creek Walkers Creek	HUC-12
0103	Brown's Creek East Fork Brown's Creek West Fork Brown's Creek Pages Branch	DA
0105	Cummings Branch Drakes Branch Dry Fork Earthman Fork Ewing Creek Little Creek Whites Creek	HUC-12
0106	Bosley Springs Branch Jocelyn Hollow Branch Murphy Road Branch Richland Creek Sugartree Creek Unnamed Trib to Richland Creek Vaughns Gap Branch	HUC-12
0201	Mill Creek (upper)	DA
0202	Finley Branch Mill Creek (lower) Pavillion Branch Sevenmile Creek Shasta Branch Sims Branch	HUC-12

Note: HUC-12 = HUC-12 Subwatershed
DA = Waterbody Drainage Area

8.3 TMDL Analysis Methodology

TMDLs for the Lower Cumberland Watershed were developed using load duration curves for analysis of impaired HUC-12 subwatersheds or specific waterbody drainage areas. A load duration curve (LDC) is a cumulative frequency graph that illustrates existing water quality conditions (as represented by loads calculated from monitoring data), how these conditions compare to desired targets, and the portion of the waterbody flow zone represented by these existing loads. Load duration curves are considered to be well suited for analysis of periodic monitoring data collected by grab sample. LDCs were developed at monitoring site locations in impaired waterbodies and daily loading functions were expressed for TMDLs, WLAs, LAs, and MOS. In addition, load reductions (PLRGs) for each flow zone were calculated for prioritization of implementation measures according to the methods described in Appendix E.

8.4 Critical Conditions and Seasonal Variation

The critical condition for non-point source E. coli loading is an extended dry period followed by a rainfall runoff event. During the dry weather period, E. coli bacteria builds up on the land surface, and is washed off by rainfall. The critical condition for point source loading occurs during periods of low streamflow when dilution is minimized. Both conditions are represented in the TMDL analysis.

The ten-year period from October 1, 1995 to September 30, 2005 was used to simulate flow. This 10-year period contained a range of hydrologic conditions that included both low and high streamflows. Critical conditions are accounted for in the load duration curve analyses by using the entire period of flow and water quality data available for the impaired waterbodies.

In all subwatersheds, water quality data have been collected during most flow ranges. For each Subwatershed, the critical flow zone has been identified based on the incremental levels of impairment relative to the target loads. Based on the location of the water quality exceedances on the load duration curves and the distribution of critical flow zones, no one delivery mode for E. coli appears to be dominant for waterbodies in the Lower Cumberland watershed (see Section 9.1.2 and 9.1.3 and Appendix E).

Seasonal variation was incorporated in the load duration curves by using the entire simulation period and all water quality data collected at the monitoring stations. The water quality data were collected during all seasons.

8.5 Margin of Safety

There are two methods for incorporating MOS in TMDL analysis: a) implicitly incorporate the MOS using conservative model assumptions; or b) explicitly specify a portion of the TMDL as the MOS and use the remainder for allocations. For development of pathogen TMDLs in the Lower Cumberland Watershed, an explicit MOS, equal to 10% of the E. coli water quality targets (ref.: Section 5.0), was utilized for determination of WLAs and LAs:

Instantaneous Maximum (lakes, reservoirs, State Scenic Rivers, Tier II and Tier III waterbodies): MOS = 49 CFU/100 ml

Instantaneous Maximum (all other waterbodies): MOS = 94 CFU/100 ml

30-Day Geometric Mean: MOS = 13 CFU/100 ml

8.6 Determination of TMDLs

E. coli daily loading functions were calculated for impaired segments in the Lower Cumberland watershed using LDCs to evaluate compliance with the single maximum target concentrations according to the procedure in Appendix C. These TMDL loading functions for impaired segments and subwatersheds are shown in Table 8.

8.7 Determination of WLAs & LAs

WLAs for MS4s and LAs for precipitation induced sources of E. coli loading were determined according to the procedures in Appendix C. These allocations represent the available loading <u>after application of the explicit MOS</u>. WLAs for existing WWTFs are equal to their existing NPDES permit limits. Since WWTF permit limits require that E. coli concentrations must comply with water quality criteria (TMDL targets) at the point of discharge and recognition that loading from these facilities are generally small in comparison to other loading sources, further reductions were not considered to be warranted. WLAs for CAFOs and LAs for “other direct sources” (non-precipitation induced) are equal to zero. WLAs, & LAs are summarized in Table 8.

Table 8 TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Lower Cumberland Watershed (HUC 05130202)

HUC-12 Subwatershed (05130202__) or Drainage Area (DA)	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	MOS	WLAs			LAs
					WWTFs [a]	Leaking Collection Systems	MS4s	
			[CFU/day]	[CFU/day]	[CFU/day]	[CFU/day]	[CFU/day/acre]	[CFU/day/acre]
0101	Cooper Creek	TN05130202209 – 1000	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	8.862×10^{6}* Q	8.862×10^{6}* Q
	Dry Creek	TN05130202027 – 1000	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	3.826×10^{6} * Q	3.826×10^{6} * Q
	Gibson Creek	TN05130202212 – 1000	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	7.727×10^{6} * Q	7.727×10^{6} * Q
	Neeleys Branch	TN05130202212 – 0100	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	1.526×10^{7} * Q	1.526×10^{7} * Q
0102	Lumsley Fork	TN05130202220 – 0100	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	1.008×10^{7} * Q	1.008×10^{7} * Q
	Manskers Creek	TN05130202220 – 1000	1.20×10^{10} * Q	1.20×10^{9} * Q	NA	0	3.697×10^{5} * Q	3.697×10^{5} * Q
	Manskers Creek	TN05130202220 – 2000	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	1.200×10^{6} * Q	1.200×10^{6} * Q
	Slaters Creek	TN05130202220 – 0300	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	4.374×10^{6} * Q	4.374×10^{6} * Q
	Walkers Creek	TN05130202220 – 0200	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	2.979×10^{6} * Q	2.979×10^{6} * Q
0103	Browns Creek	TN05130202023 – 1000	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	2.070×10^{6} * Q	2.070×10^{6} * Q
	Browns Creek	TN05130202023 – 2000	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	2.150×10^{6} * Q	2.150×10^{6} * Q
	East Fork Browns Creek	TN05130202023 – 0100	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	1.810×10^{7} * Q	1.810×10^{7} * Q
	West Fork Browns Creek	TN05130202023 – 0300	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	9.526×10^{6} * Q	9.526×10^{6} * Q
	Pages Branch	TN05130202202 – 1000	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	1.072×10^{7} * Q	1.072×10^{7} * Q
	Pages Branch	TN05130202202 – 2000	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	1.707×10^{7} * Q	1.707×10^{7} * Q
0105	Cummings Branch	TN05130202010 – 0600	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	1.433×10^{7} * Q	1.433×10^{7} * Q
	Drakes Branch	TN05130202010 – 0200	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	1.663×10^{7} * Q	1.663×10^{7} * Q
	Dry Fork	TN05130202010 – 0300	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	7.594×10^{6} * Q	7.594×10^{6} * Q

Table 8 (cont'd) TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Lower Cumberland Watershed (HUC 05130202)

HUC-12 Subwatershed (05130202__) or Drainage Area (DA)	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	MOS	WLAs			LAs
					WWTFs [a]	Leaking Collection Systems	MS4s	
			[CFU/day]	[CFU/day]	[CFU/day]	[CFU/day]	[CFU/day/acre]	[CFU/day/acre]
0105	Earthman Fork	TN05130202010 – 0400	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	5.158×10^{6} * Q	5.158×10^{6} * Q
	Ewing Creek	TN05130202010 – 0800	1.20×10^{10} * Q	1.20×10^{9} * Q	NA	0	1.273×10^{6} * Q	1.273×10^{6} * Q
	Little Creek	TN05130202010 – 0700	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	6.263×10^{6} * Q	6.263×10^{6} * Q
	Whites Creek	TN05130202010 – 1000	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	5.251×10^{5} * Q	5.251×10^{5} * Q
0106	Bosley Springs Branch	TN05130202314 – 0300	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	1.434×10^{7} * Q	1.434×10^{7} * Q
	Jocelyn Hollow Branch	TN05130202314 – 0800	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	1.249×10^{7} * Q	1.249×10^{7} * Q
	Murphy Road Branch	TN05130202314 – 0200	1.20×10^{10} * Q	1.20×10^{9} * Q	NA	0	2.166×10^{7} * Q	2.166×10^{7} * Q
	Richland Creek	TN05130202314 – 1000	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	1.214×10^{6} * Q	1.214×10^{6} * Q
	Richland Creek	TN05130202314 – 2000	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	7.055×10^{5} * Q	7.055×10^{5} * Q
	Richland Creek	TN05130202314 – 3000	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	1.605×10^{6} * Q	1.605×10^{6} * Q
	Sugartree Creek	TN05130202314 – 0400	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	6.917×10^{6} * Q	6.917×10^{6} * Q
	Unnamed Tributary to Richland Creek	TN05130202314 – 0100	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	1.457×10^{8} * Q	1.457×10^{8} * Q
	Vaughns Gap Branch	TN05130202314 – 0700	1.20×10^{10} * Q	1.20×10^{9} * Q	NA	0	5.950×10^{6} * Q	5.950×10^{6} * Q
	Vaughns Gap Branch	TN05130202314 – 0750	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	1.140×10^{7} * Q	1.140×10^{7} * Q
0201	Mill Creek	TN05130202007 – 5000	1.20×10^{10} * Q	1.20×10^{9} * Q	NA	0	4.876×10^{5} * Q	4.876×10^{5} * Q
0202	Finley Branch	TN05130202007 – 0300	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	5.951×10^{7} * Q	5.951×10^{7} * Q
	Mill Creek	TN05130202007 – 3000	1.20×10^{10} * Q	1.20×10^{9} * Q	NA	0	2.467×10^{5} * Q	2.467×10^{5} * Q
	Pavillion Branch	TN05130202007 – 1500	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	3.685×10^{7} * Q	3.685×10^{7} * Q

Table 8 (cont'd) TMDLs, WLAs, & LAs expressed as daily loads for Impaired Waterbodies in the Lower Cumberland Watershed (HUC 05130202)

HUC-12 Subwatershed (05130202__) or Drainage Area (DA)	Impaired Waterbody Name	Impaired Waterbody ID	TMDL	MOS	WLAs			LAs
					WWTFs [a]	Leaking Collection Systems	MS4s	
			[CFU/day]	[CFU/day]	[CFU/day]	[CFU/day]	[CFU/day/acre]	[CFU/day/acre]
0202	Sevenmile Creek	TN05130202007 – 1400	1.20×10^{10} * Q	1.20×10^{9} * Q	NA	0	9.941×10^{5} * Q	9.941×10^{5} * Q
	Sevenmile Creek	TN05130202007 – 1450	1.20×10^{10} * Q	1.20×10^{9} * Q	NA	0	2.289×10^{6} * Q	2.289×10^{6} * Q
	Shasta Branch	TN05130202007 – 1410	2.30×10^{10} * Q	2.30×10^{9} * Q	NA	0	4.901×10^{7} * Q	4.901×10^{7} * Q
	Sims Branch	TN05130202007 – 0100	1.20×10^{10} * Q	1.20×10^{9} * Q	NA	0	4.005×10^{6} * Q	4.005×10^{6} * Q

Notes: NA = Not Applicable.

a. WLAs for WWTFs are expressed as E. coli loads (CFU/day). All current and future WWTFs must meet water quality standards at the point of discharge as specified in their NPDES permit; at no time shall concentration be greater than the appropriate E. coli standard (487 CFU/100 mL or 941 CFU/100 mL).

9.0 IMPLEMENTATION PLAN

The TMDLs, WLAs, and LAs developed in Section 8 are intended to be the first phase of a long-term effort to restore the water quality of impaired waterbodies in the Lower Cumberland watershed through reduction of excessive E. coli loading. Adaptive management methods, within the context of the State's rotating watershed management approach, will be used to modify TMDLs, WLAs, and LAs as required to meet water quality goals.

TMDL implementation activities will be accomplished within the framework of Tennessee's Watershed Approach (ref: http://www.state.tn.us/environment/wpc/watershed/). The Watershed Approach is based on a five-year cycle and encompasses planning, monitoring, assessment, TMDLs, WLAs/LAs, and permit issuance. It relies on participation at the federal, state, local and non-governmental levels to be successful.

9.1 Application of Load Duration Curves for Implementation Planning

The Load Duration Curve (LCD) methodology (Appendix C) is a form of water quality analysis and presentation of data that aids in guiding implementation by targeting management strategies for appropriate flow conditions. One of the strengths of this method is that it can be used to interpret possible delivery mechanisms of E. coli by differentiating between point and non-point source problems. The load duration curve analysis can be utilized for implementation planning. See Cleland (2003) for further information on duration curves and TMDL development, and: http://www.tmdls.net/tipstools/docs/TMDLsCleland.pdf .

9.1.1 Flow Zone Analysis for Implementation Planning

A major advantage of the duration curve framework in TMDL development is the ability to provide meaningful connections between allocations and implementation efforts (USEPA, 2006). Because the flow duration interval serves as a general indicator of hydrologic condition (i.e., wet versus dry and to what degree), allocations and reduction goals can be linked to source areas, delivery mechanisms, and the appropriate set of management practices. The use of duration curve zones (e.g., high flow, moist, mid-range, dry, and low flow) allows the development of allocation tables (USEPA, 2006) (Appendix E), which can be used to guide potential implementation actions to most effectively address water quality concerns.

For the purposes of implementation strategy development, available E. coli data are grouped according to flow zones, with the number of flow zones determined by the HUC-12 subwatershed or drainage area size, the total contributing area (for non-headwater HUC-12s), and/or the baseflow characteristics of the waterbody. In general, for drainage areas greater than 40 square miles, the duration curves will be divided into five zones (Figure 13): high flows (exceeded 0-10% of the time), moist conditions (10-40%), median or mid-range flows (40-60%), dry conditions (60-90%), and low flows (90-100%). For smaller drainage areas, flows occurring in the low flow zone (baseflow conditions) are often extremely low and difficult to measure accurately. In many small drainage areas, extreme dry conditions are characterized by zero flow for a significant percentage of time. For this reason, the low flow zone is best characterized as a broader range of conditions (or percent time) with subsequently fewer flow zones. Therefore, for most HUC-12 subwatershed drainage areas less than 40 square miles, the duration curves will be divided into four zones: high flows (exceeded 0-10% of the time), moist conditions (10-40%), median or mid-range flows (40-70%), and low flows (70-100%). Some small (<40 mi^2) waterbody drainage areas have sustained baseflow (no zero flows) throughout their period of record. For these waterbodies, the duration curves will be divided into five zones.

Given adequate data, results (allocations and percent load reduction goals) will be calculated for all flow zones; however, less emphasis is placed on the upper 10% flow range for pathogen (E. coli) TMDLs and implementation plans. The highest 10 percent flows, representing flood conditions, are considered non-recreational conditions: unsafe for wading and swimming. Humans are not expected to enter the water due to the inherent hazard from high depths and velocities during these flow conditions. As a rule of thumb, the *USGS Field Manual for the Collection of Water Quality Data* (Lane, 1997) advises its personnel not to attempt to wade a stream for which values of depth (ft) multiplied by velocity (ft/s) equal or exceed 10 ft^2/s to collect a water sample. Few observations are typically available to estimate loads under these adverse conditions due to the difficulty and danger of sample collection. Therefore, in general, the 0-10% flow range is beyond the scope of pathogen TMDLs and subsequent implementation strategies.

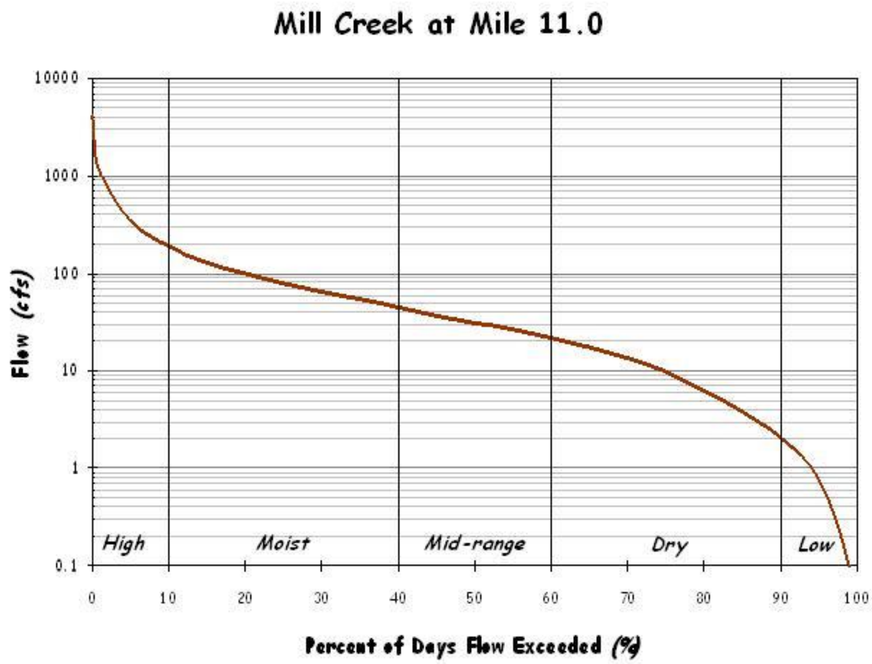

Figure 13. Five-Zone Flow Duration Curve for Mill Creek at RM 11.0

9.1.2 Existing Loads and Percent Load Reductions

Each impaired waterbody has a characteristic set of pollutant sources and existing loading conditions that vary according to flow conditions. In addition, maximum allowable loading (assimilative capacity) of a waterbody varies with flow. Therefore, existing loading, allowable loading, and percent load reduction expressed at a single location on the LDC (for a single flow condition) do not appropriately represent the TMDL in order to address all sources under all flow conditions (i.e., at all times) to satisfy implementation objectives. The LDC approach provides a methodology for determination of assimilative capacity and existing loading conditions of a waterbody for each flow zone. Subsequently, each flow zone, and the sources contributing to impairment under the corresponding flow conditions, can be evaluated independently. Lastly, the critical flow zone (with the highest percent load reduction goal) can be identified for prioritization of implementation actions.

Existing loading is calculated for each individual water quality sample as the product of the sample flow (cfs) times the single sample E. coli concentration (times a conversion factor). A percent load reduction is calculated for each water quality sample as that required to reduce the existing loading to the product of the sample flow (cfs) times the single sample maximum water quality standard (times a conversion factor). For samples with negative percent load reductions (non-exceedance: concentration below the single sample maximum water quality criterion), the percent reduction is assumed to be zero. The percent load reduction goal (PLRG) for a given flow zone is calculated a s the mean of all the percent load reductions for a given flow zone. See Appendix E.

9.1.3 Critical Conditions

The critical condition for each impaired waterbody is defined as the flow zone with the largest PLRG, excluding the “high flow” zone because these extremely high flows are not representative of recreational flow conditions, as described in Section 9.1.1. If the PLRG in this zone is greater than all the other zones, the zone with the second highest PLRG will be considered the critical flow zone. The critical conditions are such that if water quality standards were met under those conditions, they would likely be met overall.

9.2 Point Sources

9.2.1 NPDES Regulated Municipal and Industrial Wastewater Treatment Facilities

All present and future discharges from industrial and municipal wastewater treatment facilities are required to be in compliance with the conditions of their NPDES permits at all times, including elimination of bypasses and overflows. In Tennessee, permit limits for treated sanitary wastewater require compliance with coliform water quality standards (ref: Section 5.0) prior to discharge. No additional reduction is required. WLAs for WWTFs are derived from facility design flows and permitted E. coli limits and are expressed as average loads in CFU per day.

9.2.2 NPDES Regulated Municipal Separate Storm Sewer Systems (MS4s)

For present and future regulated discharges from municipal separate storm sewer systems (MS4s), WLAs are and will be implemented through Phase I & II MS4 permits. These permits will require the development and implementation of a Storm Water Management Program (SWMP) that will reduce the discharge of pollutants to the "maximum extent practicable" and not cause or contribute to violations of State water quality standards. Both the *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems* (TDEC, 2003) and the TDOT individual MS4 permit (TNS077585) require SWMPs to include minimum control measures. The permits also contain requirements regarding control of discharges of pollutants of concern into impaired waterbodies, implementation of provisions of approved TMDLs, and descriptions of methods to evaluate whether storm water controls are adequate to meet the requirements of approved TMDLs.

For guidance on the six minimum control measures for MS4s regulated under Phase I or Phase II, a series of fact sheets are available at: http://cfpub1.epa.gov/npdes/stormwater/swfinal.cfm?program_id=6 .

For further information on Tennessee's *NPDES General Permit for Discharges from Small Municipal Separate Storm Sewer Systems*, see: http://state.tn.us/environment/wpc/ppo/TN%20Small%20MS4%20Modified%General%20Permit%20 2003.pdf .

In order to evaluate SWMP effectiveness and demonstrate compliance with specified WLAs, MS4s must develop and implement appropriate monitoring programs. An effective monitoring program could include:

- Effluent monitoring at selected outfalls that are representative of particular land uses or geographical areas that contribute to pollutant loading before and after implementation of pollutant control measures.
- Analytical monitoring of pollutants of concern (e.g., monthly) in receiving waterbodies, both upstream and downstream of MS4 discharges, over an extended period of time. In addition, intensive collection of pollutant monitoring data during the recreation season (June – September) at sufficient frequency to support calculation of the geometric mean.

When applicable, the appropriate Division of Water Pollution Control Environmental Field Office should be consulted for assistance in the determination of monitoring strategies, locations, frequency, and methods within 12 months after the approval date of TMDLs or designation as a regulated MS4. Details of the monitoring plans and monitoring data should be included in annual reports required by MS4 permits.

9.2.3 NPDES Regulated Concentrated Animal Feeding Operations (CAFOs)

WLAs provided to most CAFOs will be implemented through NPDES Permit No. TNA000000, General NPDES Permit for *Class II Concentrated Animal Feeding Operation* or the facility's individual permit. Provisions of the general permit include development and implementation of Nutrient Management Plan (NMPs), requirements regarding land application BMPs, and requirements for CAFO liquid waste manatement systems. For further information, see: http://state.tn.us/environment/wpc/ppo/CAFO%20Final%20PDF%20Modified.pdf .

9.3 Nonpoint Sources

The Tennessee Department of Environment & Conservation has no direct regulatory authority over most nonpoint source (NPS) discharges. Reductions of E. coli loading from nonpoint sources will be achieved using a phased approach. Voluntary, incentive-based mechanisms will be used to implement NPS management measures in order to assure that measurable reductions in pollutant loadings can be achieved for the targeted impaired waters. Cooperation and active participation by the general public and various industry, business, and environmental groups is critical to successful implementation of TMDLs. There are links to a number of publications and information resources on EPA's Nonpoint Source Pollution web page (http://www.epa.gov/owow/nps/pubs.html) relating to the implementation and evaluation of nonpoint source pollution control measures.

Local citizen-led and implemented management measures have the potential to provide the most efficient and comprehensive avenue for reduction of loading rates from nonpoint sources. An excellent example of stakeholder involvement is the Cumberland River Coalition. The Cumberland River Compact is a non-profit group made up of businesses, individuals, community organizations, and agencies working in the Cumberland River watershed. Members of the Compact work with educators, landowners, contractors, marinas and other interested groups to coordinate informational education programs that encourage all of us to be better stewards of our water resources. The Compact works with local, state and federal agencies and officials to promote and strengthen cooperative working relationships and encourage the development of reliable, easy-to-understand data about water quality. Members of the Compact work with local communities to develop watershed forums where citizens come together to learn more about their watershed and participate in developing a shared vision for the future. The Compact also serves as a clearing-house of available public education programs to landowner assistance. Information regarding the accomplishments of the Cumberland River Compact is available at their website:

http://www.cumberlandrivercompact.org/.

9.3.1 Urban Nonpoint Sources

Management measures to reduce pathogen loading from urban nonpoint sources are similar to those recommended for MS4s (Sect. 9.2.2). Specific categories of urban nonpoint sources include stormwater, illicit discharges, septic systems, pet waste, and wildlife:

Stormwater: Most mitigation measures for stormwater are not designed specifically to reduce bacteria concentrations (ENSR, 2005). Instead, BMPs are typically designed to remove sediment and other pollutants. Bacteria in stormwater runoff are, however, often attached to particulate matter. Therefore, treatment systems that remove sediment may also provide reductions in bacteria concentrations.

Illicit discharges: Removal of illicit discharges to storm sewer systems, particularly of sanitary wastes, is an effective means of reducing pathogen loading to receiving waters (ENSR, 2005). These include intentional illegal connections from commercial or residential buildings, failing septic systems, and improper disposal of sewage from campers and boats.

Septic systems: When properly installed, operated, and maintained, septic systems effectively reduce pathogen concentrations in sewage. To reduce the release of pathogens, practices can be employed to maximize the life of existing systems, identify failed systems, and replace or remove failed systems (USEPA, 2005a). Alternatively, the installation of public sewers may be appropriate.

Pet waste: If the waste is not properly disposed of, these bacteria can wash into storm drains or directly into water bodies and contribute to pathogen impairment. Encouraging pet owners to properly collect and dispose of pet waste is the primary means for reducing the impact of pet waste (USEPA, 2002b).

Wildlife: Reducing the impact of wildlife on pathogen concentrations in waterbodies generally requires either reducing the concentration of wildlife in an area or reducing their proximity to the waterbody (ENSR, 2005). The primary means for doing this is to eliminate human inducements for congregation. In addition, in some instances population control measures may be appropriate.

Two additional urban nonpoint source resource documents provided by EPA are:

National Management Measures to Control Nonpoint Source Pollution from Urban Areas (http://www.epa.gov/owow/nps/urbanmm/index.html) helps citizens and municipalities in urban areas protect bodies of water from polluted runoff that can result from everyday activities. The scientifically sound techniques techniques it presents are among the best practices known today. The guidance will also help states to implement their nonpoint source control programs and municipalities to implement their Phase II Storm Water Permit Programs (Publication Number EPA 841-B-05-004, November 2005).

The Use of Best Management Practices (BMPs) in Urban Watersheds (http://www.epa.gov/nrmrl/pubs/600r04184/600r04184chap1.pdf) is a comprehensive literature review on commonly used urban watershed Best Management Practices (BMPs) that heretofore was not consolidated. The purpose of this document is to serve as an information source to individuals and agencies/municipalities/watershed management groups/etc. on the existing state of BMPs in urban stormwater management (Publication Number EPA/600/R-04/184, September 2004).

9.3.2 Agricultural Nonpoint Sources

BMPs have been utilized in the Lower Cumberland watershed to reduce the amount of coliform bacteria transported to surface waters from agricultural sources. These BMPs (e.g., animal waste management systems, waste utilization, stream stabilization, fencing, heavy use area treatment, livestock exclusion, etc.) may have contributed to reductions in in-stream concentrations of coliform bacteria in one or more Lower Cumberland watershed E. coli-impaired subwatersheds during the TMDL evaluation period. The Tennessee Department of Agriculture (TDA) keeps a database of BMPs implemented in Tennessee. Those listed in the Lower Cumberland watershed are shown in Figure 14. It is recommended that additional information (e.g., livestock access to streams, manure application practices, etc.) be provided and evaluated to better identify and quantify agricultural sources of coliform bacteria loading in order to minimize uncertainty in future modeling efforts.

It is further recommended that additional BMPs be implemented and monitored to document performance in reducing coliform bacteria loading to surface waters from agricultural sources. Demonstration sites for various types of BMPs should be established and maintained, and their performance (in source reduction) evaluated over a period of at least two years prior to recommendations for utilization for subsequent implementation. E. coli sampling and monitoring are recommended during low-flow (baseflow) and storm periods at sites with and without BMPs and/or before and after implementation of BMPs.

For additional information on agricultural BMPs in Tennessee, see: http://state.tn.us/agriculture/nps/bmpa.ntml .

An additional agricultural nonpoint source resource provided by EPA is *National Management Measures to Control Nonpoint Source Pollution from Agriculture* (http://www.epa.gov/owow/nps/agmm/index.html): a technical guidance and reference document for use by State, local, and tribal managers in the implementation of nonpoint source pollution management programs. It contains information on the best available, economically achievable means of reducing pollution of surface and groundwater from agriculture (EPA 841-B-03-004, July 2003).

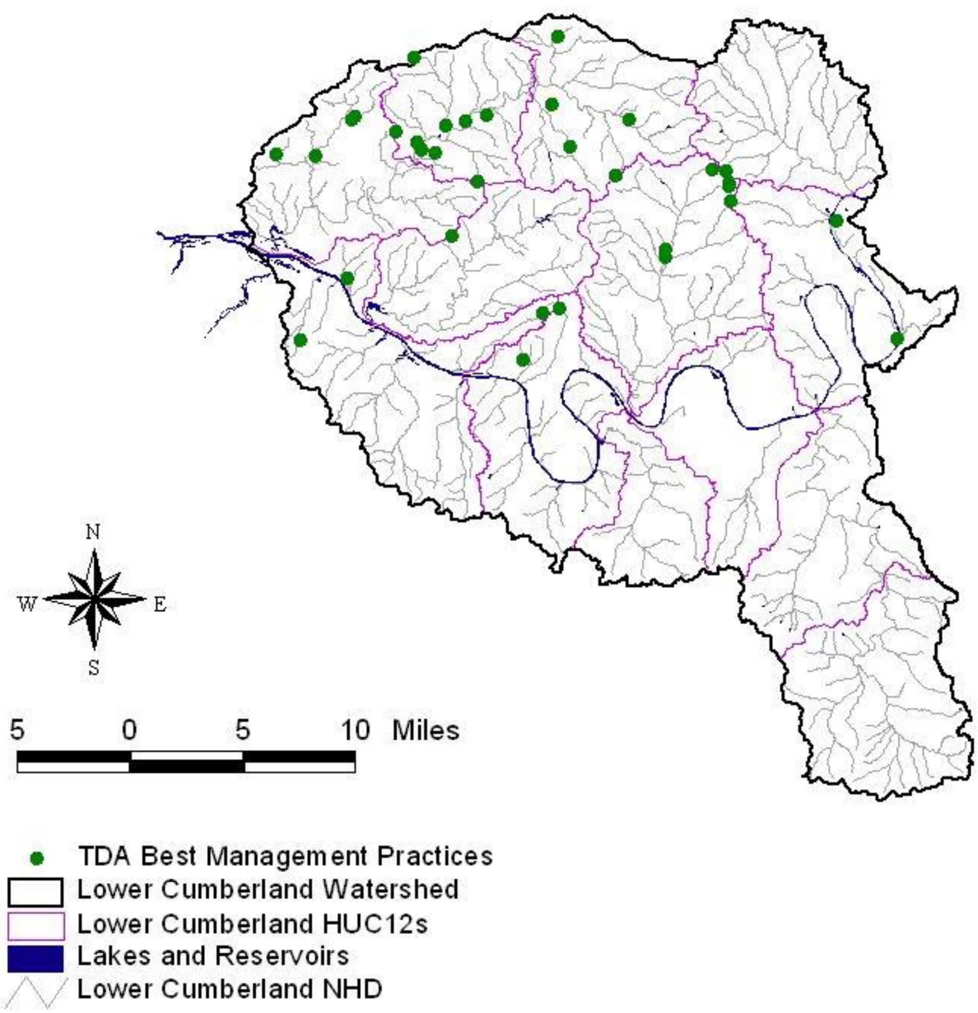

Figure 14. Tennessee Department of Agriculture Best Management Practices located in the Lower Cumberland Watershed.

9.3.3 Other Nonpoint Sources

Additional nonpoint source references (not specifically addressing urban and/or agricultural sources) provided by EPA include:

National Management Measures to Control Nonpoint Source Pollution from Forestry (http://www.epa.gov/owow/nps/forestrymgmt/) helps forest owners protect lakes and streams from polluted runoff that can result from forestry activities. These scientifically sound techniques are the best practices known today. The report will also help states to implement their nonpoint source control programs (EPA 841-B-05-001, May 2005).

In addition, the EPA website, http://www.epa.gov/owow/nps/bestnpsdocs.html , contains a list of guidance documents endorsed by the Nonpoint Source Control Branch at EPA headquarters. The list includes documents addressing urban, agriculture, forestry, marinas, stream restoration, nonpoint source monitoring, and funding.

9.4 Additional Monitoring

Additional monitoring and assessment activities are recommended to determine whether implementation of TMDLs, WLAs, & LAs in tributaries and upstream reaches will result in achievement of in-stream water quality targets for E. coli.

9.4.1 Water Quality Monitoring

Activities recommended for the Lower Cumberland watershed:

Verify the assessment status of stream reaches identified on the Final 2006 303(d) List as impaired due to E. coli. If it is determined that these stream reaches are still not fully supporting designated uses, then sufficient data to enable development of TMDLs should be acquired. TMDLs will be revisited on 5-year watershed cycle as described above.

Evaluate the effectiveness of implementation measures (see Sect. 9.6). Includes BMP performance analysis and monitoring by permittees and stakeholders. Where required TMDL loading reduction has been fully achieved, adequate data to support delisting should be collected.

Continue ambient (long-term) monitoring at appropriate sites and key locations.

Comprehensive water quality monitoring activities include sampling during all seasons and a broad range of flow and meteorological conditions. In addition, collection of E. coli data at sufficient frequency to support calculation of the geometric mean, as described in Tennessee's General Water Quality Criteria (TDEC, 2004a), is encouraged. Finally, for individual monitoring locations, where historical E. coli data are greater than 1000 colonies/100 mL (or future samples are anticipated to be), a 1:100 dilution should be performed as described in Protocol A of the *Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water* (TDEC, 2004b).

9.4.2 Source Identification

An important aspect of E. coli load reduction activities is the accurate identification of the actual sources of pollution. In cases where the sources of E. coli impairment are not readily apparent, Microbial Source Tracking (MST) is one approach to determining the sources of fecal pollution and E. coli affecting a waterbody. Those methods that use bacteria as target organisms are also known as Bacterial Source Tracking (BST) methods. This technology is recommended for source identification in E. coli impaired waterbodies.

Bacterial Source Tracking is a collective term used for various emerging biochemical, chemical, and molecular methods that have been developed to distinguish sources of human and non-human fecal pollution in environmental samples (Shah, 2004). In general, these methods rely on genotypic (also known as "genetic fingerprinting"), or phenotypic (relating to the physical characteristics of an organism) distinctions between the bacteria of different sources. Three primary genotypic techniques are available for BST: ribotyping, pulsed field gel electrophoresis (PFGE), and polymerase chain reaction (PCR). Phenotypic techniques generally involve an antibiotic resistance analysis (Hyer, 2004).

The USEPA has published a fact sheet that discusses BST methods and presents examples of BST application to TMDL development and implementation (USEPA, 2002b). Various BST projects and descriptions of the application of BST techniques used to guide implementation of effective BMPs to remove or reduce fecal contamination are presented. The fact sheet can be found on the following EPA website: http://www.epa.gov/owm/mtb/bacsortk.pdf.

A multi-disciplinary group of researchers at the University of Tennessee, Knoxville (UTK) has developed and tested a series of different microbial assay methods based on real-time PCR to detect fecal bacterial concentrations and host sources in water samples (McKay, 2005). The assays have been used in a study of fecal contamination and have proven useful in identification of areas where cattle represent a significant fecal input and in development of BMPs. It is expected that these types of assays could have broad applications in monitoring fecal impacts from Animal Feeding Operations, as well as from wildlife and human sources. Additional information can be found on the following UTK website: http://web.utk.edu/~hydro/Research?McKayAGU2004Abstract.pdf .

BST technology was utilized in a study conducted in Stock Creek (Little River watershed) (Layton, 2004). Microbial source tracking using real-time PCR assays to quantify *Bacteroides* 16S rRNA genes was used to determine the percent of fecal contamination attributable to cattle. E. coli loads attributable to cattle were calculated for each of nine sampling sites in the Stock Creek subwatershed on twelve sampling dates. At the site on High Bluff Branch (tributary to Stock Creek), none of the sample dates had E. coli loads attributable to cattle above the threshold. This suggests that at this site removal of E. coli attributable to cattle would have little impact on the total E. coli loads. The E. coli load attributable to cattle made a large contribution to the total E. coli load at each of the eight remaining sampling sites. At two of the sites (STOCK005.3KN and GHOLL000.6KN), 50–75% of the E. coli attributable to cattle loads alone was above the 126 CFU/100mL threshhold. This suggests that removal of the E. coli attributable to cattle at these sites would reduce the total E. coli load to acceptable limits.

9.5 Source Area Implementation Strategy

Implementation strategies are organized according to the dominant landuse type and the sources associated with each (Table 9 and Appendix E). Each HUC-12 subwatershed is grouped and targeted for implementation based on this source area organization. Three primary categories are identified: predominantly urban, predominantly agricultural, and mixed urban/agricultural. See Appendix A for information regarding landuse distributation of impaired subwatersheds. For the purpose of implementation evaluation, urban is defined as residential, commercial, and industrial landuse areas with predominant source categories such as point sources (WWTFs), collection systems/septic systems (including SSOs and CSOs), and urban stormwater runoff associated with MS4s. Agricultural is defined as cropland and pasture, with predominant source categories associated with livestock and manure management activities. A fourth category (infrequent) is associated with forested (including non-agricultural undeveloped and unaltered [by humans]) landuse areas with the predominant source category being wildlife.

All impaired waterbodies and corresponding HUC-12 subwatersheds or drainage areas have been classified according to their respective source area types in Table 9. The implementation for each area will be prioritized according to the guidance provided in Sections 9.5.1 and 9.5.2, below. For all impaired waterbodies, the determination of source area types serves to identify the predominant sources contributing to impairment (i.e., those that should be targeted initially for implementation). However, it is not intended to imply that sources in other landuse areas are not contributors to impairment and/or to grant an exemption from addressing other source area contributions with implementation strategies and corresponding load reduction. For mixed use areas, implementation will follow the guidance established for both urban and agricultural areas, at a minimum.

Appendix E provides source area implementation examples for urban and agricultural subwatersheds, development of percent load reduction goals, and determination of critical flow zones (for implementation prioritization) for E. coli impaired waterbodies. Load duration curve analyses (TMDLs, WLAs, LAs, and MOS) and percent load reduction goals for all flow zones for all E. coli impaired waterbodies in the Lower Cumberland watershed are summarized in Table E-73.

Table 9. Source area types for waterbody drainage area analyses.

Waterbody ID	Source Area Type*			
	Urban	Agricultural	Mixed	Forested
Cooper Creek	✓			
Dry Creek			✓	
Gibson Creek	✓			
Neeleys Branch	✓			
Lumsley Fork			✓	
Manskers Creek (1000)			✓	
Manskers Creek (2000)			✓	

Table 9 (cont'd). Source area types for waterbody drainage area analyses.

Waterbody ID	Source Area Type*			
	Urban	Agricultural	Mixed	Forested
Slaters Creek			✓	
Walkers Creek			✓	
Browns Creek (1000)	✓			
Browns Creek (2000)	✓			
East Fork Browns Creek	✓			
West Fork Browns Creek	✓			
Pages Branch (1000)	✓			
Pages Branch (2000)	✓			
Cummings Branch		✓		
Drakes Branch			✓	
Dry Fork			✓	
Earthman Fork			✓	
Ewing Creek			✓	
Little Creek			✓	
Whites Creek			✓	
Bosley Springs Branch	✓			
Jocelyn Hollow Branch	✓			
Murphy Road Branch	✓			
Richland Creek (1000)	✓			
Richland Creek (2000)	✓			
Richland Creek (3000)	✓			
Sugartree Creek	✓			
Unnamed Tributary to Richland Creek	✓			
Vaughns Gap Branch	✓			
Mill Creek (5000)		✓		
Finley Branch	✓			
Mill Creek (3000)	✓			

Table 9 (cont'd). Source area types for waterbody drainage area analyses.

Waterbody ID	Source Area Type*			
	Urban	Agricultural	Mixed	Forested
Pavillion Branch	✓			
Sevenmile Creek (1400)	✓			
Sevenmile Creek (1450)	✓			
Shasta Branch	✓			
Sims Branch			✓	

* All waterbodies potentially have significant source contributions from other source type/landuse areas.

9.5.1 Urban Source Areas

For impaired waterbodies and corresponding HUC-12 subwatersheds or drainage areas classified as predominantly urban, implementation strategies for E. coli load reduction will initially and primarily target source categories similar to those listed in Table 10 (USEPA, 2006). Table 10 presents example urban area management practices and the corresponding potential relative effectiveness under each of the hydrologic flow zones. Each implementation strategy addresses a range of flow conditions and targets point sources, non-point sources, or a combination of each. For each waterbody, the existing loads and corresponding PLRG for each flow zone are calculated according to the method described in Section E.4. The resulting determination of the critical flow zone further focuses the types of urban management practices appropriate for development of an effective load reduction strategy for a particular waterbody.

9.5.2 Agricultural Source Areas

For impaired waterbodies and corresponding HUC-12 subwatersheds or drainage areas classified as predominantly agricultural, implementation strategies for E. coli load reduction will initially and primarily target source categories similar to those listed in Table 11 (USDA, 1988). Table 11 present example agricultural area management practices and the corresponding potential relative effectiveness under each of the hydrologic flow zones. Each implementation strategy addresses a range of flow conditions and targets point sources, non-point sources, or a combination of each. For each waterbody, the existing loads and corresponding PLRG for each flow zone are calculated according to the method described in Section E.4. The resulting determination of the critical flow zone further focuses the types of agricultural management practices appropriate for development of an effective load reduction strategy for a particular waterbody.

9.5.3 Forestry Source Areas

There are no impaired waterbodies with corresponding HUC-12 subwatersheds or drainage areas classified as source area type predominantly forested, with the predominant source category being wildlife, in the Lower Cumberland watershed.

Table 10. Example Urban Area Management Practice/Hydrologic Flow Zone Considerations.

Management Practice	Duration Curve Zone (Flow Zone)				
	High	Moist	Mid-Range	Dry	Low
Bacteria source reduction					
Remove illicit discharges			L	M	H
Address pet & wildlife waste		H	M	M	L
Combined sewer overflow management					
Combined sewer separation		H	M	L	
CSO prevention practices		H	M	L	
Sanitary sewer system					
Infiltration/Inflow mitigation	H	M	L	L	
Inspection, maintenance, and repair		L	M	H	H
SSO repair/abatement	H	M	L		
Illegal cross-connections					
Septic system management					
Managing private systems		L	M	H	M
Replacing failed systems		L	M	H	M
Installing public sewers		L	M	H	M
Storm water infiltration/retention					
Infiltration basin		L	M	H	
Infiltration trench		L	M	H	
Infiltration/Biofilter swale		L	M	H	
Storm Water detention					
Created wetland		H	M	L	
Low impact development					
Disconnecting impervious areas		L	M	H	
Bioretention	L	M	H	H	
Pervious pavement		L	M	H	
Green Roof		L	M	H	
Buffers		H	H	H	
New/existing on-site wastewater treatment systems					
Permitting & installation programs		L	M	H	M
Operation & maintenance programs		L	M	H	M
Other					
Point source controls		L	M	H	H
Landfill control		L	M	H	
Riparian buffers		H	H	H	

Table 10 (cont'd). Example Urban Area Management Practice/Hydrologic Flow Zone Considerations.

Management Practice	Duration Curve Zone (Flow Zone)				
	High	Moist	Mid-Range	Dry	Low
Pet waste education & ordinances		M	H	H	L
Wildlife management		M	H	H	L
Inspection & maintenance of BMPs	L	M	H	H	L

Note: Potential relative importance of management practice effectiveness under given hydrologic condition (*H: High, M: Medium, L: Low*)

Table 11. Example Agricultural Area Management Practice/Hydrologic Flow Zone Considerations.

Flow Condition	High	Moist	Mid-range	Dry	Low
% Time Flow Exceeded	0-10	10-40	40-60	60-90	90-100
Grazing Management					
Prescribed Grazing (528A)	**H**	**H**	**M**	**L**	
Pasture & Hayland Mgmt (510)	**H**	**H**	**M**	**L**	
Deferred Grazing (352)	**H**	**H**	**M**	**L**	
Planned Grazing System (556)	**H**	**H**	**M**	**L**	
Proper Grazing Use (528)	**H**	**H**	**M**	**L**	
Proper Woodland Grazing (530)	**H**	**H**	**M**	**L**	
Livestock Access Limitation					
Livestock Exclusion (472)			**M**	**H**	**H**
Fencing (382)			**M**	**H**	**H**
Stream Crossing			**M**	**H**	**H**
Alternate Water Supply					
Pipeline (516)			**M**	**H**	**H**
Pond (378)			**M**	**H**	**H**
Trough or Tank (614)			**M**	**H**	**H**
Well (642)			**M**	**H**	**H**
Spring Development (574)			**M**	**H**	**H**

Table 11 (cont'd). Example Agricultural Area Management Practice/Hydrologic Flow Zone Considerations.

Flow Condition	High	Moist	Mid-range	Dry	Low
% Time Flow Exceeded	0-10	10-40	40-60	60-90	90-100
Manure Management					
Managing Barnyards	**H**	**H**	**M**	**L**	
Manure Transfer (634)	**H**	**H**	**M**	**L**	
Land Application of Manure	**H**	**H**	**M**	**L**	
Composting Facility (317)	**H**	**H**	**M**	**L**	
Vegetative Stabilization					
Pasture & Hayland Planting (512)	**H**	**H**	**M**	**L**	
Range Seeding (550)	**H**	**H**	**M**	**L**	
Channel Vegetation (322)	**H**	**H**	**M**	**L**	
Brush (& Weed) Mgmt (314)	**H**	**H**	**M**	**L**	
Conservation Cover (327)		**H**	**H**	**H**	
Riparian Buffers (391)		**H**	**H**	**H**	
Critical Area Planting (342)		**H**	**H**	**H**	
Wetland restoration (657)		**H**	**H**	**H**	
CAFO Management					
Waste Management System (312)	**H**	**H**	**M**		
Waste Storage Structure (313)	**H**	**H**	**M**		
Waste Storage Pond (425)	**H**	**H**	**M**		
Waste Treatment Lagoon (359)	**H**	**H**	**M**		
Mulching (484)	**H**	**H**	**M**		
Waste Utilization (633)	**H**	**H**	**M**		
Water & Sediment Control Basin (638)	**H**	**H**	**M**		
Filter Strip (393)	**H**	**H**	**M**		
Sediment Basin (350)	**H**	**H**	**M**		
Grassed Waterway (412)	**H**	**H**	**M**		
Diversion (362)	**H**	**H**	**M**		
Heavy Use Area Protection (561)					

Table 11 (cont'd). Example Agricultural Area Management Practice/Hydrologic Flow Zone Considerations.

Flow Condition	High	Moist	Mid-range	Dry	Low
% Time Flow Exceeded	0-10	10-40	40-60	60-90	90-100
CAFO Management (cont'd)					
Constructed Wetland (656)					
Dikes (356)	**H**	**H**	**M**		
Lined Waterway or Outlet (468)	**H**	**H**	**M**		
Roof Runoff Mgmt (558)	**H**	**H**	**M**		
Floodwater Diversion (400)	**H**	**H**	**M**		
Terrace (600)	**H**	**H**	**M**		
Potential for source area contribution under given hydrologic condition (H: High; M: Medium; L: Low)					

Note: Numbers in parentheses are the U.S. Soil Conservation Service practice number.

9.6 Evaluation of TMDL Implementation Effectiveness

Evaluation of the effectiveness of TMDL implementation strategies should be conducted on multiple levels, as appropriate:

- HUC-12 or waterbody drainage area (i.e., TMDL analysis location)
- Subwatersheds or intermediate sampling locations
- Specific landuse areas (urban, pasture, etc.)
- Specific facilities (WWTF, CAFO, uniquely identified portion of MS4, etc.)
- Individual BMPs

In order to conduct an implementation effectiveness analysis on measures to reduce E. coli source loading, monitoring results should be evaluated in one of several ways. Sampling results can be compared to water quality standards (e.g., load duration curve analysis) for determination of impairment status, results can be compared on a before and after basis (temporal), or results can be evaluated both upstream and downstream of source reduction measures or source input (spatial). Considerations include period of record, data collection frequency, representativeness of data, and sampling locations.

In general, periods of record greater than 5 years (given adequate sampling frequency) can be evaluated for determination of relative change (trend analysis). For watershed in second or successive TMDL cycles, data collected from multiple cycles can be compared. If implementation efforts have been initiated to reduce loading, evaluation of routine monitoring data may indicate improving or worsening conditions over time and corresponding effectiveness of implementation efforts.

Water quality data for implementation effectiveness analysis can be presented in multiple ways. For example, Figure 15 shows fecal coliform concentration data statistics for Oostanaula Creek at mile 28.4 (Hiwassee River watershed) for a historical (2002) TMDL analysis period versus a recent post-implementation period of sampling data (revised TMDL). The individual flow zone analyses are presented in a box and whisker plot of recent [2] versus historical [1] data. Figure 16 shows a load duration curve analysis (of recent versus historical data) of fecal coliform loading statistics for Oostanaula Creek. Lastly, Figure 17 shows best fit curve analyses of flow (percent time exceeded) versus fecal coliform loading relationships (regressions) plotted against the LDC of the single sample maximum water quality standard. Note that Figures 15-17 present the same data, from approved TMDLs (2 cycles), each clearly illustrating improving conditions between historical and recent periods.

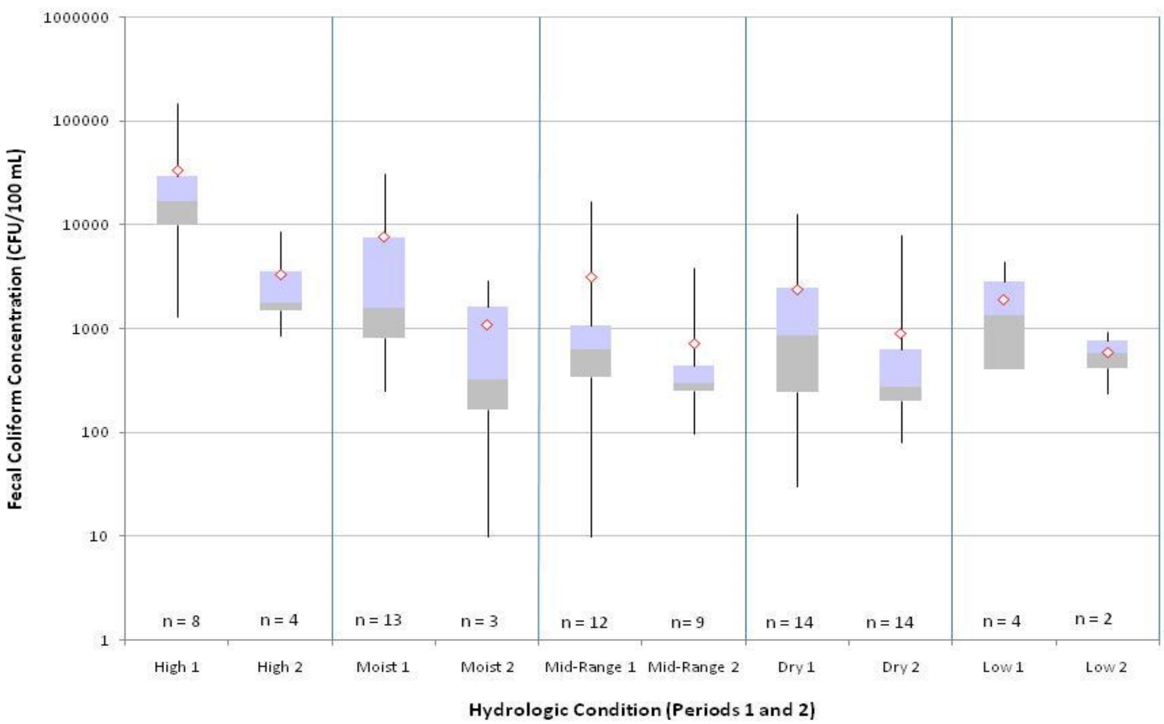

Figure 15. Oostanaula Creek TMDL implementation effectiveness (box and whisker plot).

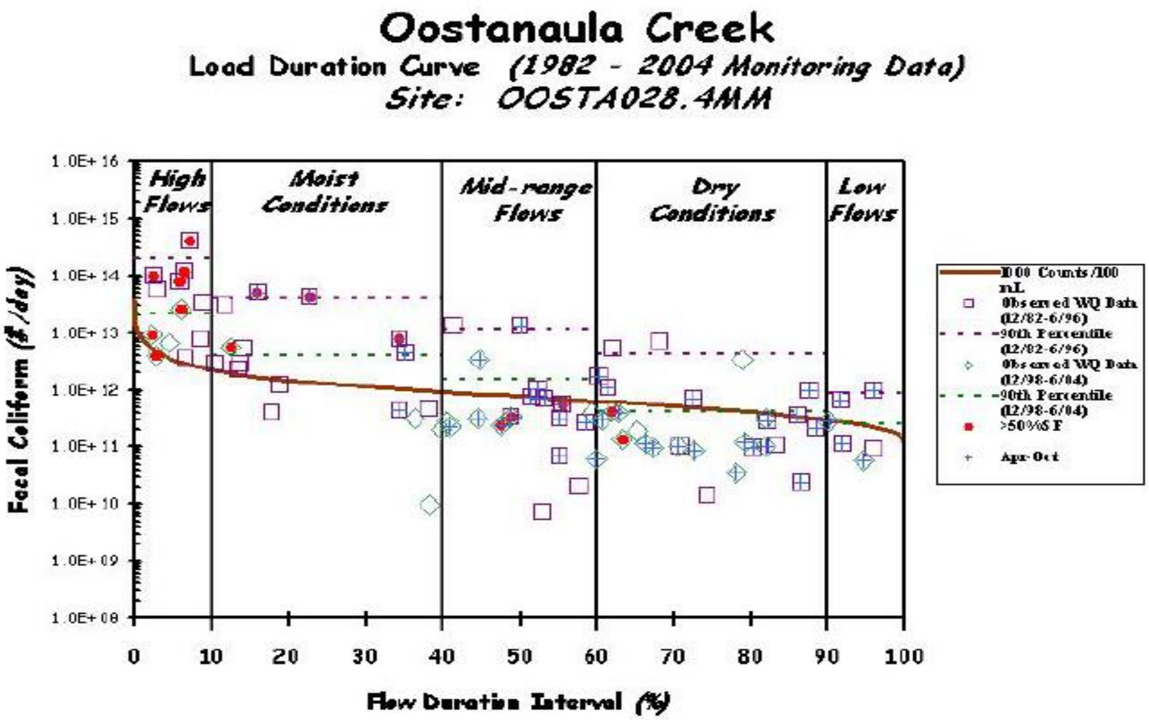

Figure 16. Oostanaula Creek TMDL implementation effectiveness (LDC analysis).

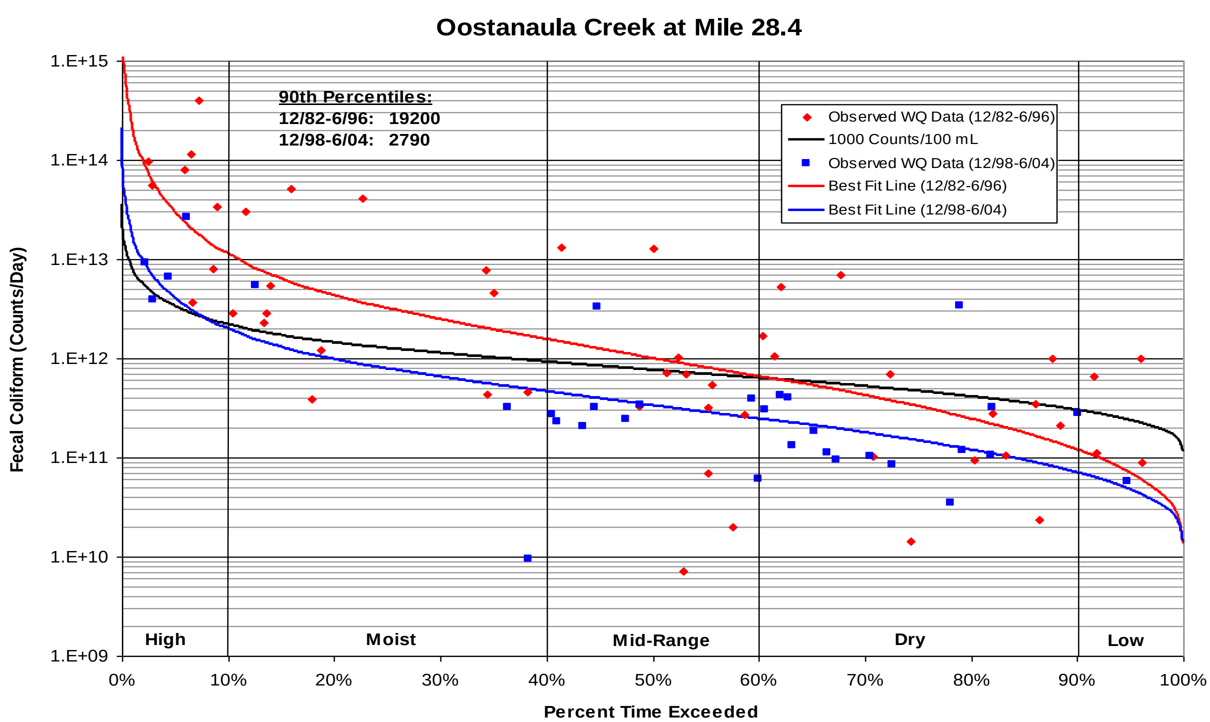

Figure 17. Oostanaula Creek TMDL implementation effectiveness (LDC regression analysis).

10.0 PUBLIC PARTICIPATION

In accordance with 40 CFR §130.7, the proposed pathogen TMDLs for the Lower Cumberland Watershed was placed on Public Notice for a 35-day period and comments solicited. Steps that were taken in this regard include:

1) Notice of the proposed TMDLs was posted on the Tennessee Department of Environment and Conservation website. The announcement invited public and stakeholder comment and provided a link to a downloadable version of the TMDL document.

2) Notice of the availability of the proposed TMDLs (similar to the website announcement) was included in one of the NPDES permit Public Notice mailings which is sent to approximately 90 interested persons or groups who have requested this information.

3) Letters were sent to WWTFs located in E. coli-impaired subwatersheds or drainage areas in the Lower Cumberland Watershed, permitted to discharge treated effluent containing pathogens, advising them of the proposed TMDLs and their availability on the TDEC website. The letters also stated that a copy of the draft TMDL document would be provided on request. A letter was sent to the following facilities:

   Nashville Central STP (TN0020575)
   Nashville Dry Creek STP (TN0020648)
   Nashville Whites Creek STP (TN0024970)
   Hendersonville Shopping Center (TN0058106)

4) A draft copy of the proposed TMDL was sent to those MS4s that are wholly or partially located in E. coli-impaired subwatersheds. A draft copy was sent to the following entities:

   City of Belle Meade, Tennessee (TNS075159)
   City of Berry Hill, Tennessee (TNS075167)
   City of Forest Hills, Tennessee (TNS075302)
   City of Goodlettsville, Tennessee (TNS075345)
   City of Hendersonville, Tennessee (TNS075353)
   City of Millersville, Tennessee (TNS077887)
   City of Nolensville, Tennessee (TNS077801)
   City of Oak Hill, Tennessee (TNS075477)
   City of Nashville/Davidson County, Tennessee (TNS068047)
   Sumner County, Tennessee (TNS075680)
   Williamson County, Tennessee (TNS075795)
   Tennessee Dept. of Transportation (TNS077585)

5) A letter was sent to water quality partners in the Lower Cumberland Watershed advising them of the proposed pathogen TMDLs and their availability on the TDEC website. The letter also stated that a written copy of the draft TMDL document would be provided upon request. A letter was sent to the following partners:

   Cumberland Coalition
   Cumberland River Compact
   Mid-Cumberland Watershed Committee
   Tennessee Wildlife Federation
   Natural Resources Conservation Service
   Tennessee Valley Authority
   United States Forest Service
   Tennessee Department of Agriculture
   Tennessee Wildlife Resources Agency
   The Nature Conservancy

No comments were received during the public notice period.

11.0 FURTHER INFORMATION

Further information concerning Tennessee's TMDL program can be found on the Internet at the Tennessee Department of Environment and Conservation website:

http://www.state.tn.us/environment/wpc/tmdl/

Technical questions regarding this TMDL should be directed to the following members of the Division of Water Pollution Control staff:

Vicki S. Steed, P.E., Watershed Management Section
e-mail: Vicki.Steed@state.tn.us

Sherry H. Wang, Ph.D., Watershed Management Section
e-mail: Sherry.Wang@state.tn.us

REFERENCES

Center for Watershed Protection, 1999. *Watershed Protection Techniques*. Vol. 3. No. 1. Center for Watershed Protection. Ellicott City, MD. April 1999.

Cleland, Bruce, 2003. *TMDL Development from the "Bottom Up" – Part III: Duration Curves and Wet-Weather Assessments*. America's Clean Water Foundation. Washington, DC. September 2003. This document can be found at TMDLs.net, a joint effort of America's Clean Water Foundation, the Association of State and Interstate Water Pollution Control Administrators, and EPA: http://www.tmdls.net/tipstools/docs/TMDLsCleland.pdf.

ENSR. 2005. *Mitigation Measures to Address Pathogen Pollution in Surface Waters: A TMDL Implementation Guidance Manual for Massachusetts*. Prepared by ENSR International for U.S. Environmental Protection Agency, Region 1. July 2005.

Hyer, Kenneth E., and Douglas L. Moyer, 2004. *Enhancing Fecal Coliform Total Maximum Daily Load Models Through Bacterial Source Tracking*. Journal of the American Water Resources Association (JAWRA) 40(6):1511-1526. Paper No. 03180.

Lane, S. L., and R. G. Fay, 1997. *National Field Manual for the Collection of Water-Quality Data, Chapter A9. Safety in Field Activities: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. 9*. October 1997. This document is available on the USGS website: http://water.usgs.gov/owq/FieldManual/Chap9/content.html.

Layton, Alice, Gentry, Randy, and McKay, Larry, 2004. *Calculation of Stock Creek E. coli loads and partitioning of E. coli loads in to that attributable to bovine using Bruce Cleland's Flow Duration Curve Models*. Personal note.

Lumb, A.M., McCammon, R.B., and Kittle, J.L., Jr., 1994, *Users Manual for an expert system, (HSPFEXP) for calibration of the Hydrologic Simulation Program – Fortran*: U.S. Geological Survey Water-Resources Investigation Report 94-4168,102 p.

McKay, Larry, Layton, Alice, and Gentry, Randy, 2005. *Development and Testing of Real-Time PCR Assays for Determining Fecal Loading and Source Identification (Cattle, Human, etc.) in Streams and Groundwater.* This document is available on the UTK website: http://web.utk.edu/~hydro/Research/McKayAGU2004abstract.pdf .

Metro Nashville and Davidson County, 2005. *Annual Report: Year 2 – Permit Cycle 2*. This document is available on the OAP website: http://www.nashvilleoap.com/.

Shah, Vikas G., Hugh Dunstan, and Phillip M. Geary, 2004. *Application of Emerging Bacterial Source Tracking (BST) Methods to Detect and Distinguish Sources of Fecal Pollution in Waters.* School of Environmental and Life Sciences, The University of Newcastle, Callaghan, NSW 2308 Australia. This document is available on the University of Newcastle website: http://www.newcastle.edu.au/discipline/geology/staff_pg/pgeary/BacterialSourceTracking.pdf.

Stiles, T., and B. Cleland, 2003, Using Duration Curves in TMDL Development & Implementation Planning. ASIWPCA "States Helping States" Conference Call, July 1, 2003. This document is available on the Indiana Office of Water Quality website: http://www.in.gov/idem/water/planbr/wqs/tmdl/durationcurveshscall.pdf .

TDEC. 2003. *General Permit for Discharges from Small Municipal Separate Storm Sewer Systems.* State of Tennessee, Department of Environment and Conservation, Division of Water Pollution Control, February 2003. This document is available on the TDEC website: http://www.state.tn.us/environment/wpc/stormh2o/MS4II.htm.

TDEC. 2004a. *State of Tennessee Water Quality Standards, Chapter 1200-4-3 General Water Quality Criteria, January 2004.* State of Tennessee, Department of Environment and Conservation, Division of Water Pollution Control.

TDEC. 2004b. *Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water.* State of Tennessee, Department of Environment and Conservation, Division of Water Pollution Control.

TDEC. 2006. *Final 2006 303(d) List*. State of Tennessee, Department of Environment and Conservation, Division of Water Pollution Control, October 2006.

USDA, 1988. *1-4 Effects of Conservation Practices on Water Quantity and Quality*. In *Water Quality Workshop, Integrating Water Quality and Quantity into Conservation Planning*. U.S. Department of Agriculture, Soil Conservation Service. Washington, D.C.

USDA, 2004. *2002 Census of Agricultue, Tennessee State and County Data, Volume 1, Geographic Area Series, Part 42 (AC-02-A-42)*. USDA website URL: http://www.nass.usda.gov/census/census02/volume1/tn/index2.htm . June 2004.

USEPA. 1991. *Guidance for Water Quality –based Decisions: The TMDL Process.* U.S. Environmental Protection Agency, Office of Water, Washington, DC. EPA-440/4-91-001, April 1991.

USEPA. 1997. *Ecoregions of Tennessee*. U.S. Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, Corvallis, Oregon. EPA/600/R-97/022.

USEPA, 2002a. *Animal Feeding Operations Frequently Asked Questions*. USEPA website URL: http://cfpub.epa.gov/npdes/faqs.cfm?program_id=7 . September 12, 2002.

USEPA, 2002b. *Wastewater Technology Fact Sheet, Bacterial Source Tracking*. U.S. Environmental Protection Agency, Office of Water. Washington, D.C. EPA 832-F-02-010, May 2002. This document is available on the EPA website: http://www.epa.gov/owm/mtb/bacsortk.pdf.

USEPA. 2003. *National Management Measures to Control Nonpoint Source Pollution from Agriculture*. EPA 841-B-03-004. U.S. Environmental Protection Agency. Washington, DC. This document is available on the EPA website: http://www.epa.gov/owow/nps/agmm/index.html.

USEPA. 2004. *The Use of Best Management Practices (BMPs) in Urban Watersheds*. U.S. Environmental Protection Agency, Office of Research and Development. Washington, D.C. EPA/600/R-04/184, September 2004.

USEPA. 2005a. *National Management Measures to Control Nonpoint Source Pollution from Urban Areas*. U.S. Environmental Protection Agency, Office of Water. Washington, D.C. EPA 841-B-05-004, November 2005. This document is available on the EPA website: http://www.epa.gov/owow/nps/urbanmm/index.html.

USEPA. 2005b. *National Management Measures to Control Nonpoint Source Pollution from Forestry*. U.S. Environmental Protection Agency, Office of Water. Washington, D.C. EPA 841-B-05-001, May 2005. This document is available on the EPA website: http://www.epa.gov/owow/nps/forestrymgmt/.

USEPA, 2006. *An Approach for Using Load Duration Curves in Developing TMDLs.* U.S. Environmental Protection Agency, Office of Wetlands, Oceans, & Watersheds. Washington, D.C. Draft, December 2006.